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Before the  
Federal Communications Commission  
Washington, D.C. 20554

In the Matter of

Mitigation of Orbital Debris

IB Docket No. 02-54

## SECOND REPORT AND ORDER

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By the Commission:

### TABLE OF CONTENTS

	<u>Para. No.</u>
I. INTRODUCTION.....	1
II. BACKGROUND.....	2
A. Nature of Orbital Debris.....	2
B. Prior Commission Actions Regarding Orbital Debris.....	7
III. DISCUSSION	
A. FCC Statutory Authority Regarding Orbital Debris.....	12
B. Disclosure of Orbital Debris Mitigation Plans.....	15
C. Specific Elements of Orbital Debris Mitigation.....	22
1. Spacecraft Hardware Design: Control of Debris Released During Normal Operations; Selection of a Safe Operational Configuration; Collisions with Small Debris.....	23
2. Minimizing Debris Generated by Accidental Explosions.....	29
3. Safe Flight Profiles: Collisions with Large Objects.....	34
a. Application Information Requirements.....	35
b. Pre-Operational Phase.....	38
c. On-Orbit Operations.....	41
d. Coordination of Maneuvers.....	52
4. Post-Mission Disposal.....	58
a. GEO Space Stations.....	64
(i) Grandfathering.....	77
b. NGSO Space Stations.....	83
c. Fuel Matters.....	89
D. Scope of Rules.....	92
1. Non-U.S.-Licensed Space Stations.....	92
2. Amateur and Experimental Licensees.....	98

3.	NOAA-Licensed Space Stations.....	102
4.	Launch Vehicles.....	105
E.	Liability Issues and Insurance.....	109
F.	Other Matters.....	114
IV.	CONCLUSION.....	117
V.	PROCEDURAL MATTERS.....	118
A.	Final Regulatory Flexibility Act Analysis.....	118
B.	Final Paperwork Reduction Act of 1995 Analysis.....	119
VI.	ORDERING CLAUSES.....	121
Appendix A – Parties Filing Pleadings		
Appendix B – Rule Revisions		
Appendix C – Final Regulatory Flexibility Analysis		

## I. INTRODUCTION

1. In this Second Report and Order, we amend Parts 5, 25, and 97 of the Commission's rules by adopting new rules concerning mitigation of orbital debris.<sup>1</sup> Adoption of these rules will help preserve the United States' continued affordable access to space, the continued provision of reliable U.S. space-based services – including communications and remote sensing satellite services for U.S. commercial, government, and homeland security purposes – as well as the continued safety of persons and property in space and on the surface of the Earth. Under the rules as amended today, a satellite system operator requesting FCC space station authorization, or an entity requesting a Commission ruling for access to a non-U.S.-licensed space station under our satellite market access procedures, must submit an orbital debris mitigation plan to the Commission regarding spacecraft design and operation in connection with its request. This Second Report and Order provides guidance for the preparation of such plans. We also adopt requirements concerning the post-mission disposal of Commission-licensed space stations<sup>2</sup> operating in or near the two most heavily used orbital regimes, low-Earth orbit (LEO),<sup>3</sup> and geostationary-Earth orbit (GEO).<sup>4</sup> Adoption of these rules will further the domestic policy objective of

<sup>1</sup> 47 C.F.R. Parts 5 [Experimental Radio Service], 25 [Satellite Communications], and 97 [Amateur Radio Service] (2002).

<sup>2</sup> As used in this Second Report and Order, the term "space station" has the meaning given in the International Telecommunication Union (ITU) Radio Regulations, *i.e.*, one or more transmitters or receivers or a combination of transmitters and receivers necessary for carrying on a radiocommunication service, and located on an object which is beyond, is intended to go beyond, or has been beyond, the major portion of the Earth's atmosphere. See ITU Radio Regulations S1.61 and S1.64.

<sup>3</sup> For purposes of this Second Report and Order, the term LEO is used to refer to the orbits at altitudes below 2,000 kilometers.

<sup>4</sup> GEO is a circular orbit along the plane of the Earth's equator at an altitude of approximately 35,786 kilometers. A spacecraft in geostationary-Earth orbit can be maintained at a constant longitudinal position relative to the Earth, thus allowing the satellite to be "seen" continuously from, and at a fixed orientation to, any given point on the Earth's surface. See Physical Nature and Technical Attributes of the Geostationary Orbit, Study Prepared by the

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the United States to minimize the creation of orbital debris and is consistent with international policies and initiatives to achieve this goal.<sup>5</sup>

## II. BACKGROUND

### A. Nature of Orbital Debris

2. As explained in detail in the Notice of Proposed Rulemaking in this proceeding (*Orbital Debris Notice* or *Notice*),<sup>6</sup> orbital debris consists of artificial objects orbiting the Earth that are not functional spacecraft. It consists of a wide range of non-functioning man-made objects that have been placed into the Earth's orbit, both accidentally and on purpose. Orbital debris ranges in size from small objects, such as paint flakes, solid rocket motor slag, and break-up debris, to larger objects, such as discarded lens caps or ejected bolts.<sup>7</sup> The largest items, in terms of mass, include spacecraft, rocket bodies, and the largest pieces of debris from exploded spacecraft and rocket bodies.<sup>8</sup> The U.S. Department of Defense's Space Surveillance Network (SSN) has catalogued approximately 9,000 individual orbital debris objects currently in orbit and routinely tracks over 11,000 objects in orbit sized 10 centimeters or greater.<sup>9</sup> Furthermore, it is estimated that there are currently in orbit more than one hundred thousand objects between 1.0 and 10 centimeters and several million objects between 0.1 and 1 centimeters.<sup>10</sup>

3. The majority of space operations take place in a limited number of orbital regimes. The first of these regimes is low-Earth orbit. LEO is used by a number of Earth observation satellites, as well as by global mobile-satellite telephony services such as Iridium and Globalstar. LEO is also used for manned spaceflight, such as the Space Shuttle and the International Space Station. The second regime is geostationary-Earth orbit. GEO is used for the majority of satellite video, voice, and data services, as well as for direct-to-home and direct broadcast satellite services. Because of its ability to allow a spacecraft to appear "fixed" relative to the Earth, GEO is a unique and limited natural resource. In addition to LEO and GEO, there are other orbital regimes. Medium-Earth orbit (MEO) utilizes altitudes between LEO and GEO, typically around 20,200 kilometers, to provide a range of communications and navigational services.<sup>11</sup> Space operations may also utilize highly elliptical orbits (HEO). HEO spacecraft

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Secretariat, United Nations Committee on the Peaceful Uses of Outer Space, UN Document A/AC.105/404 (January 13, 1988). (Copy available in the docket file of this proceeding).

<sup>5</sup> For further discussion of U.S. and international policies regarding orbital debris, see Section II.B., *infra*.

<sup>6</sup> *Mitigation of Orbital Debris*, Notice of Proposed Rulemaking, IB Docket No. 02-34, FCC 02-80, 17 FCC Rcd 5586 (2002).

<sup>7</sup> *Id.* at 5588. The term "slag" is used here to refer to material, often aluminum oxide, ejected from solid rocket motors as a by-product of the burning of solid rocket propellants.

<sup>8</sup> Nicholas L. Johnson "Overview of NASA Orbital Debris Program," slides presented 27 January 1998 at the U.S. Government Orbital Debris Workshop for Industry. (Copy available in the docket file of this proceeding.) National Research Council Committee on Space Debris, Aeronautics and Engineering Board, Commission on Engineering and Technical Systems, *Orbital Debris: A Technical Assessment* (National Academy Press, Washington, D.C. 1995) at 199 (*Orbital Debris: A Technical Assessment*). Available online via [www.orbitaldebris.jsc.nasa.gov](http://www.orbitaldebris.jsc.nasa.gov).

<sup>9</sup> United States Space Command website, available on-line at <http://www.spacecom.mil/factsheetshtml/reentryassessment.htm>.

<sup>10</sup> See White House Office of Science and Technology Policy, Interagency Report on Orbital Debris (1995) (*1995 Interagency Report*) at 6, Table 2.

<sup>11</sup> For example, the U.S. Global Positioning System (GPS) operates at altitudes of approximately 20,000 kilometers, and the Russian Global Navigation Satellite System (GLONASS) operates at altitudes around 19,000 kilometers.

typically have perigees (i.e., the point of orbit closest to the Earth) at LEO or MEO altitudes and have apogeos (i.e., the point farthest from the Earth) ranging from altitudes in the vicinity of MEO, to altitudes above the GEO altitude.<sup>12</sup>

4. As experts have recognized for many years, orbital debris poses a potential risk to the continued reliable use of these orbital regimes for space-based services and operations, as well as to the continued safety of persons and property in space and on the surface of the Earth. The effects of collisions involving orbital debris can be severe. Objects in orbit move at a very high velocity.<sup>13</sup> Because of the high relative velocities involved, collisions involving even very small debris objects are capable of producing significant impact damage.<sup>14</sup> Even debris as small as one millimeter in diameter can cause significant structural damage to a functional spacecraft; for objects larger than one centimeter in diameter, the damage caused to functional spacecraft can be catastrophic.<sup>15</sup> Furthermore, such collisions can produce a large amount of additional debris, which can be dispersed over a wide orbital area.<sup>16</sup>

5. In addition, the orbital lifetime of debris can be extremely long. Once debris is created, it remains in orbit indefinitely, absent other forces.<sup>17</sup> Although atmospheric drag<sup>18</sup> will result in debris being removed from orbit at low altitudes, the effect of atmospheric drag decreases dramatically as the orbital altitude of an object increases. For example, while atmospheric drag will cause an object with a perigee altitude of 250 kilometers to re-enter the Earth atmosphere within approximately two months, the same object will remain in orbit typically in excess of 500 years at orbits with perigees above 850 kilometers.<sup>19</sup> At GEO, where the effects of atmospheric drag are virtually non-existent, objects can

<sup>12</sup> Use of HEO spacecraft was pioneered by the Soviet "Molniya" communications satellites, and as a result HEO is sometimes colloquially referred to as a "Molniya" orbit. See 1995 *Interagency Report* at 4. Sirius Satellite Radio, a licensee in the Satellite Digital Audio Radio Service, is an example of a Commission-licensed satellite system utilizing highly elliptical orbits with perigee altitudes of a little less than 24,500 kilometers and apogee altitudes of about 47,000 kilometers. See Satellite CD Radio, Inc., Application to Modify Authorization, File No. SAT-MOD-19981211-00099 (filed December 11, 1998).

<sup>13</sup> Orbital velocities are directly related to altitude; that is, objects in lower orbits travel faster than objects in higher orbits. Objects in LEO orbits have orbital velocities in the range of 7-8 kilometers per second (km/s). For objects in GEO, the orbital velocity is about 3 km/s. The velocity of objects in HEO varies throughout their orbits, with perigee velocities greater than objects in circular LEO orbits and with apogee velocities slower than objects in circular GEO orbits. Impact velocities for objects in circular orbits range from 0 km/s for objects colliding in virtually the same orbit, to twice the orbital velocity for head-on collisions. See Orbital Debris: A Technical Assessment at 89.

<sup>14</sup> For purposes of illustration, it is estimated that a one centimeter aluminum sphere with a mass of about 1.4 grams moving at 13 km/s would have a kinetic energy equivalent to 56 grams of TNT; a ten centimeter aluminum sphere moving at the same speed would have the equivalent of 56 kilograms of TNT. See Orbital Debris: A Technical Assessment at 93.

<sup>15</sup> 1995 *Interagency Report* at 8.

<sup>16</sup> Fragments resulting from a collision will be dispersed at a wide range of velocities, which will place them into a range of new orbits. See Orbital Debris: A Technical Assessment at 92.

<sup>17</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5588.

<sup>18</sup> Atmospheric drag is produced when molecules of gas from the Earth's atmosphere collide with the surface of the orbiting object, causing the object to lose velocity and eventually re-enter the Earth's atmosphere. See *id.* at 5588.

<sup>19</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5589. These figures were derived using NASA's debris assessment software, which is available on-line at [www.orbitaldebris.jsc.nasa.gov/mitigate/das/das.html](http://www.orbitaldebris.jsc.nasa.gov/mitigate/das/das.html). They were based on an assumed spacecraft area to mass ratio of .01 m<sup>2</sup>/kg. See *id.* at 5589 n.4.

remain in orbit in excess of a million years.<sup>20</sup> Although the natural “cleansing” of atmospheric drag results in the removal of some low-altitude debris, the overall trend is one of an increasing orbital debris population that will increase the potential for future collisions.<sup>21</sup>

6. Objects in orbit that re-enter the Earth’s atmosphere are slowed by drag as they enter the atmosphere. As a result of drag, many objects break up and/or burn up. Objects that are particularly resistant to heat and the forces experienced during re-entry may survive re-entry and reach the surface of the Earth. Although the velocity of these objects, compared to objects in orbit, is very low, the kinetic energy of such objects is sufficient to cause damage or injury at the surface of the Earth. To date, however, there has never been a confirmed incident of injury to a human being as a result of orbital debris re-entering the Earth’s atmosphere.

#### B. Prior Commission Actions Concerning Orbital Debris

7. The Commission has historically addressed issues regarding orbital debris and satellite systems on a case-by-case and service-by-service basis. In recent years, the Commission has adopted orbital debris mitigation disclosure obligations as part of the service rules for certain classes of satellite systems. For example, in 2000 the Commission adopted orbital debris mitigation rules for licensees in the 2 GHz mobile-satellite service (MSS),<sup>22</sup> and in 2002 and 2003 the Commission adopted such rules for the Ku- and Ka-band non-geostationary orbit (NGSO) fixed-satellite service (FSS).<sup>23</sup> Under these rules, applicants must disclose, as part of their license applications, “the design and operational strategies that they will use, if any, to mitigate orbital debris.”<sup>24</sup> Applicants in these services are also required to submit a “casualty risk assessment” that evaluates the probability of risk of human injury on the Earth from orbital debris if the operator plans to dispose of its spacecraft at end of life through one of the available disposal methods, atmospheric re-entry.<sup>25</sup> In each of these instances, the Commission stressed that it would continue to evaluate an applicant’s orbital debris disclosure on a case-by-case basis, but stated that it would initiate a separate rulemaking proceeding to consider the adoption of orbital debris disclosure requirements for all FCC-licensed satellite services, as well as other measures to mitigate orbital debris.<sup>26</sup>

<sup>20</sup> 1995 Interagency Report at 8; American Institute of Aeronautics and Astronautics, 6<sup>th</sup> International Space Cooperation Workshop (March 2001) (AIAA 2001 Report) at 14. (Copy available in the docket file of this proceeding).

<sup>21</sup> See Orbital Debris: A Technical Assessment at 20, Figure 1-2; Scientific and Technical Subcommittee of the United Nations Committee on Peaceful Uses of Outer Space, Technical Report on Space Debris, UN Document A/AC.105/720 (1999) (STSC Technical Report on Space Debris) at 14, Figure II; 1995 Interagency Report on Orbital Debris at 18, Figure 11.

<sup>22</sup> 47 C.F.R. § 25.143(b).

<sup>23</sup> 47 C.F.R. §§ 25.145(c)(3) and 25.146(i)(4).

<sup>24</sup> *The Establishment of Policies and Service Rules for the Mobile Satellite Service in the 2 GHz Band*, Report and Order, IB Docket No. 99-81, FCC 00-302, 15 FCC Rcd 16127, 16188 (2000) (*2 GHz MSS Order*); *The Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ku-band*, Report and Order and Further Notice of Proposed Rulemaking, IB Docket No. 01-96, FCC 02-123, 17 FCC Rcd 7841, 7865-66 (para. 81) (2002) (*NGSO FSS Ku-Band Order*); *The Establishment of Policies and Service Rules for the Non-Geostationary Satellite Orbit, Fixed Satellite Service in the Ka-Band*, IB Docket No. 02-19, FCC 03-137, 18 FCC Rcd 14708, 14725-26 (para. 55) (2003) (*NGSO FSS Ka-Band Order*).

<sup>25</sup> See, e.g., *2 GHz MSS Order*, 15 FCC Rcd at 16188.

<sup>26</sup> *2 GHz MSS Order*, 15 FCC Rcd at 16188 (para. 138); *NGSO FSS Ku-Band Order*, 17 FCC Rcd at 7866 (para. 81); *NGSO FSS Ka-Band Order*, 18 FCC Rcd at 14725-26 (para. 55).

8. The Commission initiated this rulemaking proceeding in March, 2002.<sup>27</sup> The *Orbital Debris Notice* sought comment on a wide range of proposals concerning ways to mitigate orbital debris arising from Commission-authorized space activities. Principally, the *Notice* proposed to adopt debris mitigation disclosure requirements for all types of satellite systems licensed by the Commission.<sup>28</sup> The *Notice* also sought comment on the content of such debris mitigation disclosures, and whether there are debris mitigation practices that are sufficiently developed to warrant adopting these practices as Commission rules.<sup>29</sup> In addition, the *Notice* sought comment regarding the Commission's statutory authority to adopt debris mitigation rules, the proper scope of such rules, and liability and insurance matters arising from orbital debris issues.

9. Since the release of the *Orbital Debris Notice*, the FCC has addressed orbital debris issues in a number of proceedings. Most significantly, the Commission adopted disclosure requirements concerning orbital debris mitigation measures as part of its efforts to streamline the Commission's space station licensing procedures.<sup>30</sup> Specifically, the Commission adopted a *First Report and Order* in this docket, in which it established default rules for all satellite systems that required certain classes of applicants to submit, as part of their license application, a narrative statement describing the design and operational strategies that they will use to mitigate orbital debris, as well as a casualty risk assessment if planned post-mission disposal involves atmospheric re-entry of the spacecraft.<sup>31</sup> In addition, the International Bureau has addressed orbital debris mitigation issues in a number of other proceedings.<sup>32</sup> In the absence of comprehensive orbital debris mitigation rules, each of these instances was addressed on a case-by-case basis.

10. With regards to the adoption of specific debris mitigation practices, the *Notice* based its proposals on the debris mitigation practices embodied in the U.S. Government Orbital Debris Mitigation Standard Practices (U.S. Government Standard Practices).<sup>33</sup> These practices were adopted by the U.S.

<sup>27</sup> See generally *Orbital Debris Notice*.

<sup>28</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5598.

<sup>29</sup> *Id.*

<sup>30</sup> *Amendment of the Commission's Space Station Licensing Rules and Policies, Mitigation of Orbital Debris*, First Report and Order and Further Notice of Proposed Rulemaking in IB Docket No. 02-34, First Report and Order in IB Docket No. 02-54, FCC 03-102, 18 FCC Rcd 10760 (2003) (*First Report and Order*).

<sup>31</sup> The default service rules, including the default orbital debris mitigation requirements, apply only to applications in service bands for which the Commission has not adopted service-specific service rules. See *id.* at 10784-85 (para. 53)(NGSO-like systems) and 10808 (para. 120)(GEO-like systems). This step was taken because, as part of the streamlining actions taken in our Space Station Licensing Reform proceeding, we will now approve non-GEO space stations prior to adoption of service rules. Therefore, we sought to ensure that basic information concerning debris mitigation measures is provided prior to any such approval.

<sup>32</sup> See, e.g., *EchoStar Satellite Corp.*, Order and Authorization, DA 03-2559, 18 FCC Rcd 15862 (Int'l Bur. 2003)(addressing EchoStar's compliance with any FCC orbital debris mitigation requirements as part of its request to modify its Ka-band license to include a C-band payload authorized by a foreign administration); *Applications of The Boeing Company*, Order and Authorization, DA 03-2073, 18 FCC Rcd 12317 (Int'l Bur. 2003)(reviewing Boeing's proposed orbital debris mitigation plans as part of its request for modification of its 2 GHz MSS license); *Orbital Communications Corp.*, Order and Authorization, DA 02-772, 17 FCC Rcd 6337 (Int'l Bur. 2002)(conditioning grant of licensee's request to increase the orbital altitude of a portion of its satellite constellation upon the licensee taking steps to reduce the orbital lifetime of those satellites to no more than 25 years after end of life). See also *PanAmSat Corporation, Special Temporary Authorization for the Galaxy IIIIR Satellite*, File No. SAT-STA-20030324-00039 (authorization conditioned on maintaining a satellite's capability to de-orbit to an altitude no less than 300 kilometers above GEO) (*Galaxy IIIIR STA Grant*).

<sup>33</sup> A copy of the U.S. Government Standard Practices is attached as Appendix A to the *Orbital Debris Notice*.

Government in 2000 and apply to missions operated or procured by U.S. government agencies.<sup>34</sup> The U.S. Government Standard Practices seek to control the creation of orbital debris by means of four practices: (1) control of debris during normal operations; (2) minimizing debris generated by accidental explosions; (3) selection of a safe flight profile and operational configuration; and (4) post-mission disposal of space structures. The *Orbital Debris Notice* examined the specifics of these practices and sought comment on whether each of these practices should be incorporated as a requirement for space station operators seeking Commission authorization for their space activities.<sup>35</sup>

11. The *Orbital Debris Notice* also observed that orbital debris mitigation measures have been addressed internationally. For example, in 1993 the Radiocommunication Assembly of the International Telecommunication Union (ITU-R)<sup>36</sup> adopted a debris mitigation recommendation concerning the region of space in the vicinity of GEO.<sup>37</sup> The ITU-R recommended, among other things, that as little debris as possible be released into the geostationary Earth orbit, and that a GEO satellite at the end of its life be transferred, before the complete exhaustion of its propellant, to a storage orbit at least 300 kilometers above GEO altitude. Furthermore, the Scientific and Technical Subcommittee (STSC) of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS)<sup>38</sup> adopted a comprehensive report on orbital debris in 1999.<sup>39</sup> The STSC established a multi-year work plan, to be completed in 2005, to consider orbital debris and called for the Inter-Agency Space Debris Coordination Committee (IADC)<sup>40</sup> to submit consensus debris mitigation guidelines that could be implemented by countries on a voluntary basis.<sup>41</sup> The IADC presented its consensus guidelines to the STSC in February 2003. The IADC guidelines recognize LEO and GEO as unique orbital regions that must be protected from generation of

<sup>34</sup> The U.S. Government Standard Practices were adopted in response to an interagency U.S. Government report published in November 1995. See generally *1995 Interagency Report*. The *1995 Interagency Report* recommended that that National Aeronautics and Space Administration (NASA) and the Department of Defense (DoD) jointly develop draft design guidelines that could serve as a baseline for agency requirements for future spacecraft. It also recommended that interested U.S. agencies then consult with the private sector to develop government/industry design guidelines. A draft of the U.S. Government Standard Practices was presented to industry at a 1998 U.S. government workshop for industry. See *Orbital Debris Notice*, 17 FCC Rcd at 5590.

<sup>35</sup> *Id.* at 5601-10. A list of parties filing pleadings in response to the *Notice* is provided as Appendix A.

<sup>36</sup> The ITU is a specialized agency of the United Nations. The United States is a Member State of the ITU and is a party to the ITU Constitution, Convention, and Radio Regulations.

<sup>37</sup> ITU-R S.1003, "Environmental Protection of the Geostationary-Satellite Orbit," ITU-R Recommendations, 1994 S Series Volume: Fixed Satellite Service, International Telecommunication Union, Geneva, Switzerland, 1994 at pp. 364-367.

<sup>38</sup> UNCOPUOS was established pursuant to the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (*The Outer Space Treaty*), which entered into force October 10, 1967. The United States is a party to the *Outer Space Treaty*. Over 98 countries have ratified the treaty as of January, 2003. A full text of the *Outer Space Treaty* is available on-line at <http://www.oosa.unvienna.org/SpaceLaw/treaties.html>.

<sup>39</sup> See generally *STSC Technical Report on Space Debris*.

<sup>40</sup> The IADC is an inter-governmental committee developed to enable spacefaring nations to exchange information on orbital debris research activities, to review the progress of ongoing cooperative activities, to facilitate opportunities for cooperation in orbital debris research, and to identify debris mitigation options. Members of the IADC includes the space agencies of Europe, France, Germany, India, Italy, Japan, the People's Republic of China, Russia, Ukraine, the United Kingdom, and the United States. See IADC website, available at <http://www.iadc-online.org>.

<sup>41</sup> Report of the Scientific and Technical Subcommittee on its thirty-eighth session, UN Document A/AC.105/761 (2001) at para. 130.

orbital debris in order to ensure their future safe and sustainable use. The IADC guidelines propose specific practices to protect these regions and to mitigate orbital debris in general. The STSC is reviewing the guidelines and discussing means of endorsing their utilization.<sup>42</sup> Subsequent to the release of the *Orbital Debris Notice*, the ITU revised its 1993 recommendation and adopted a formula for the post-mission disposal of GEO satellites that follows the proposal of the IADC guidelines.<sup>43</sup> In addition, individual nations, such as Japan, Russia, the Ukraine, France, Germany and India, have developed, or are in the process of developing, debris mitigation standards and practices at the national level.<sup>44</sup>

### III. DISCUSSION

#### A. FCC Statutory Authority Regarding Orbital Debris

12. *Background.* In the *Notice*, comment was sought on the basis of the Commission's statutory authority to adopt rules regarding orbital debris.<sup>45</sup> The *Notice* observed that the Commission has addressed orbital debris issues in several cases,<sup>46</sup> but has not, to date, formally addressed the scope and nature of its authority concerning orbital debris. The *Notice* analyzed the statutory responsibilities and obligations of the Commission under the Communications Act of 1934 (Communications Act or Act)<sup>47</sup> and how these responsibilities were related to the consideration of orbital debris. The *Notice* sought comment on this analysis.

13. *Discussion.* We conclude that adoption of the debris mitigation measures in this Second Report and Order is consistent with our authority and public interest obligations under the Communications Act. Only one commenter questions the Commission's authority to adopt debris mitigation rules.<sup>48</sup> That commenter does not provide any legal analysis to support its position and does not address any of the analysis provided in the *Notice*. To the contrary, we find that orbital debris mitigation issues are a valid public interest consideration in the Commission's licensing process.

<sup>42</sup> Report of the Scientific and Technical Subcommittee on its fortieth session, Committee on the Peaceful Uses of Outer Space, UN Document A/AC.105/804 (March 5, 2003).

<sup>43</sup> See ITU Recommendation S.1003, Environmental Protection of the Geostationary-satellite Orbit (revised Jan. 2004), available at [www.itu.org](http://www.itu.org).

<sup>44</sup> Nicholas Johnson, Trends and Options in the Disposal of Launch Vehicle Orbital Stages, 52<sup>nd</sup> International Astronautical Congress (Toulouse, France 2001). See also National research on space debris, safety of space objects with nuclear power sources on board and problems relating to their collision with space debris, Addendum to Note by the Secretariat, United Nations Committee on the Peaceful Uses of Outer Space, UN Document A/AC.105/789/Add.1 (March 17, 2003) (presenting Germany's "Space debris end-to-end service" project).

<sup>45</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5598-99.

<sup>46</sup> *Id.* at 5598 (citing *The Boeing Company*, Order and Authorization, DA 01-1631 16 FCC Rcd 13691 (Int'l Bur. 2001); *Celsat America, Inc.*, Order and Authorization, DA 01-1632, 16 FCC Rcd 13712 (Int'l Bur. 2001); *Constellation Communications Holdings, Inc.*, Order and Authorization, DA 01-1633, 16 FCC Rcd 13724 (Int'l Bur./OET 2001); *Globalstar, L.P.*, Order and Authorization, DA 01-1634, 16 FCC Rcd 13739 (Int'l Bur./OET 2001); *ICO Services Ltd.*, Order and Authorization, DA 01-1635, 16 FCC Rcd 13762 (Int'l Bur./OET 2001); *Iridium LLC*, Order and Authorization, DA 01-1636, 16 FCC Rcd 13778 (Int'l Bur. 2001); *Mobile Communications Holdings, Inc.*, Order and Authorization, DA 01-1637, 16 FCC Rcd 13794 (Int'l Bur./OET 2001); *TMI Communications and Co.*, Order and Authorization, DA 01-1638, 16 FCC Rcd 13808 (Int'l Bur. 2001); *Space System Licensee, et al.*, Memorandum Opinion, Order and Authorization, DA 02-307, 17 FCC Rcd 2271 (Int'l Bur. 2002)).

<sup>47</sup> Communications Act of 1934, as amended, 47 U.S.C. § 151 *et seq.*

<sup>48</sup> *Ecliptic Comments* at 4 (stating that it would be a "far reach" to relate orbital debris mitigation measures to the Commission's mandate under the Communications Act).

14. As discussed in the *Orbital Debris Notice*,<sup>49</sup> the Communications Act provides the Commission with broad authority with respect to radio communications involving the United States, except for communications involving U.S. Government radio stations.<sup>50</sup> The Act charges the FCC with encouraging “the larger and more effective use of radio in the public interest,”<sup>51</sup> and provides for licensing of radio communications,<sup>52</sup> upon a finding that the “public convenience, interest, or necessity will be served thereby.”<sup>53</sup> Satellite communications are an important component of the national and world-wide radio communications infrastructure.<sup>54</sup> Because orbital debris could affect the cost, reliability, continuity, and safety of satellite operations, orbital debris issues have a bearing upon the “larger and more effective use of radio in the public interest.” In addition, orbital debris can negatively affect the availability, integrity, and capability of new satellite systems and valuable services to the public. Thus, orbital debris and related mitigation issues are relevant in determining whether the public interest would be served by authorization of any particular satellite system, or by any particular practice or operating procedure of satellite systems.<sup>55</sup> Furthermore, debris prospectively generated from satellites licensed by, or authorized by, the FCC could affect the public interest in protecting the safety of manned space flight, as well as the safety of persons and property on the surface of the Earth. Because robotic spacecraft are typically controlled through radiocommunications links, there is a direct connection between the radiocommunications functions we are charged with licensing under the Communications Act and the physical operations of spacecraft. Accordingly, we conclude that the actions taken in this Second Report and Order are within the scope of our authority under the Communications Act.<sup>56</sup>

#### B. Disclosure of Orbital Debris Mitigation Plans

15. *Background.* In the *Orbital Debris Notice*, the Commission proposed to require, as part of the licensing process, disclosure of orbital debris mitigation plans for all types of satellite systems licensed by the FCC.<sup>57</sup> Specifically, the *Notice* proposed to adopt an orbital debris mitigation disclosure as part of the technical information that must be supplied pursuant to Section 25.114 of the Commission’s rules.<sup>58</sup> The *Notice* also sought comment on whether we should establish more detailed methodologies

<sup>49</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5598-99.

<sup>50</sup> 47 U.S.C. § 305(a). The Commerce Department’s National Telecommunication and Information Administration is responsible for assignment of frequencies for use by U.S. Government stations.

<sup>51</sup> 47 U.S.C. § 303(g).

<sup>52</sup> 47 U.S.C. § 301.

<sup>53</sup> 47 U.S.C. § 307(a).

<sup>54</sup> *First Report and Order*, 18 FCC Rcd at 10764 (para. 2)(observing that the satellite industry is a “crucial component of the global communications marketplace”).

<sup>55</sup> Courts have held that the Commission may consider public safety factors as part of its licensing procedures. See *Simmons v. FCC*, 145 F.2d 578, 579 (D.C. Cir. 1944)(finding that the “public interest, convenience and necessity clearly require the Commission to deny applications for construction which would menace air navigation”); *Deep South Broadcasting Co. v. FCC*, 278 F.2d 264, 267 (D.C. Cir. 1960)(confirming FCC authority to consider structural aspects of a radio tower as a “clearly relevant public interest consideration”). For a discussion of the FCC’s legal authority concerning orbital debris, see also MEO/LEO Constellations: U.S. Laws, Policies, and Regulations on Orbital Debris Mitigation, American Institute of Aeronautics and Astronautics Special Project No. SP-016-2-1999 (1999).

<sup>56</sup> We address questions raised in the *Notice* concerning the scope of our authority with respect to launch activities, satellites licensed by the National Oceanic and Atmospheric Administration (NOAA), and non-U.S. licensed satellites in Section III.D., *infra*.

<sup>57</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5598.

<sup>58</sup> *Id* at 5611.

for the preparation and evaluation of the debris mitigation plans submitted in the FCC authorization process.<sup>59</sup>

16. *Discussion.* We adopt the proposal of the *Notice* and amend our rules to require disclosure of orbital debris mitigation plans as part of the technical information submitted pursuant to Section 25.114 of the Commission's rules.<sup>60</sup> Disclosure of debris mitigation plans will allow the Commission and potentially affected third parties to evaluate debris mitigation plans prior to issuance of an FCC approval for communications activities in space. Disclosure may also aid in the wider dissemination of information concerning debris mitigation techniques and may provide a base-line of information that will aid in analyzing and refining those techniques. Without such disclosure, the Commission would be denied any opportunity to ascertain whether operators are in fact considering and adopting reasonable debris mitigation practices.

17. Although we expect that operators in many instances have in the past, and will in the future, practice debris mitigation out of economic self-interest,<sup>61</sup> especially when such practices increase the reliability of revenue-producing operations, these economic incentives alone may not be sufficient where debris mitigation measures either do not affect the revenue-producing operations or, in fact, limit such operations. We also note that economic incentives alone may not sufficiently motivate operators to address effects that, although resulting from their current operations, may manifest themselves decades or centuries later. By that time, the satellite's operator may be out of business or may have no economic incentive to preserve the utility of the orbital regime. Disclosure of an applicant's debris mitigation plans as part of the technical information required by Section 25.114 will allow the Commission to examine whether a space station operator has taken orbital debris mitigation into consideration, even when economic incentives may be absent. In addition, for the reasons explained throughout this Second Report and Order, mitigation of orbital debris is important for several public interest reasons, including U.S. homeland security and continued reliability of satellite radio communications.

18. A disclosure requirement should entail minimal costs for entities requesting FCC authorization. To the extent that satellite operators already take measures to consider debris mitigation, as comments by satellite operators indicate, the additional cost of disclosing these measures should not be significant. This conclusion is expressly supported by comments, which state that a disclosure requirement would not be onerous and could be met by operators.<sup>62</sup> In addition, the costs of disclosure are not unduly burdensome when balanced against the public interest benefits of preserving safe and affordable access to space.

19. We also believe that disclosure of debris mitigation plans is useful, even though in some instances work is ongoing to develop or refine desired mitigation strategies.<sup>63</sup> In this regard, we note that we are amending our rules as part of this proceeding in order to provide more concrete requirements for

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<sup>59</sup> *Id.* at 5610.

<sup>60</sup> Pursuant to Section 25.137 of the Commission's rules, the same technical information required by Section 25.114 for U.S.-licensed space stations must also be submitted by entities requesting to operate with a non-U.S.-licensed space station to serve the United States. See 47 C.F.R. § 25.137. For a more detailed discussion of the scope of our orbital debris mitigation rules and non-U.S.-licensed space stations, see Section III.D.1., *infra*.

<sup>61</sup> SIA Comments at 3-5; PanAmSat Comments at 2; SES Americom Reply at 2-4.

<sup>62</sup> Telesat Comments at 4, 6; AMSAT Comments at 10.

<sup>63</sup> Some commenters argue that the lack of "precise standards" or "clear parameters" for assessing a debris mitigation plan could lead to arbitrary application of our rules or the reduction of the plan to "just an administrative burden" on the operator. See Orbcomm Comments at 3; SIA Comments at 7.

orbital debris mitigation in certain cases, such as in the disposal of space stations at the end of life.<sup>64</sup> Where more concrete requirements are established, such as for the end-of-life disposal of GEO space stations, they will provide a basis for reviewing the sufficiency of an applicant's debris mitigation disclosure. We will continue to analyze other issues on a case-by-case basis under the public interest standard of the Communications Act. Disclosure is still useful in those situations in order to verify that operators, in fact, are considering debris mitigation issues and bringing the latest in debris mitigation techniques to bear on satellite design and operations. Disclosure will also provide flexibility to address new developments in space station design and allows the Commission to retain its discretion to grant, condition, or deny an authorization in a manner consistent with the Communications Act.

20. Accordingly, we amend our rules to require a disclosure of debris mitigation plans as part of the technical information required pursuant to Section 25.114 of the Commission's rules. We will also make conforming editorial changes to specific service rules governing the 2 GHz MSS service,<sup>65</sup> the Ku-band NGSO service,<sup>66</sup> the Ka-band NGSO service,<sup>67</sup> and our default service rules for space stations under our streamlined space station licensing procedures.<sup>68</sup> Since systems seeking FCC approvals in these services must submit the information specified in Section 25.114 of our rules, there is no longer a need to include a separate disclosure requirement for these services in the individual rule sections that establish service-by-service requirements. Parties that have requests for approval of space stations pending before the Commission shall have 30 days following publication of this Second Report and Order in the Federal Register in which to amend their requests by filing a disclosure of debris mitigation plans in a manner consistent with this Second Report and Order.

21. We decline to adopt a particular methodology for the preparation and evaluation of an applicant's orbital debris mitigation plans, except as specifically indicated in this Second Report and Order for individual debris mitigation practices, such as in the case of post-mission disposal of certain Commission-licensed space stations. Commenters did not propose the use of any specific methodology. As we observed in the *Orbital Debris Notice*,<sup>69</sup> NASA has adopted a safety standard that provides a handbook for debris mitigation analysis and activities, which is available to the public.<sup>70</sup> Unless otherwise noted in this Second Report and Order,<sup>71</sup> applicants are encouraged, but not required, to use the NASA safety standard when assessing their debris mitigation plans and preparing these plans for submission to the Commission. Although we do not adopt a particular methodology for preparing debris mitigation plans, an applicant's debris mitigation plans – like all other elements of applications for space station authorization – must constitute a concrete proposal for Commission evaluation.<sup>72</sup> The plan must identify particular methods by which a proposed satellite system will mitigate orbital debris, rather than presenting a generalized commitment to address debris mitigation at a future date or a catalogue of

<sup>64</sup> See Section III.C. *infra*.

<sup>65</sup> 47 C.F.R. § 25.143(b).

<sup>66</sup> 47 C.F.R. § 25.146(i)(4).

<sup>67</sup> 47 C.F.R. § 25.145(c)(3).

<sup>68</sup> 47 C.F.R. § 25.217(d). See also *supra*, note 31.

<sup>69</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5610.

<sup>70</sup> NASA Safety Standard, Guidelines and Assessment Procedures for Limiting Orbital Debris, NSS 1740.14 (August 1995). (Copy available at <http://www.orbitaldebris.jsc.nasa.gov>).

<sup>71</sup> For example, applicants are required to use the standards established by the NASA guidelines when performing a casualty-risk assessment for the re-entry of space craft into the Earth's atmosphere at the end of life. See Section III.C.4.b., *infra*.

<sup>72</sup> 47 C.F.R. § 25.114(b).

potential options. If an applicant's debris mitigation plans change after authorization, the changes must be submitted to the Commission by means of a request to modify the space station authorization.<sup>73</sup>

### C. Specific Elements of Orbital Debris Mitigation

22. In addition to extending the debris mitigation disclosure requirement to all satellite systems authorized by the Commission, the *Orbital Debris Notice* identified specific elements of orbital debris mitigation and sought comment on issues arising under each element. It also sought comment on whether any measures identified in the U.S. Government Standard Practices are sufficiently mature to warrant adoption of rules requiring their use.<sup>74</sup> We address each of the specific elements of orbital debris mitigation below.

#### 1. Spacecraft Hardware Design: Control of Debris Released During Normal Operations; Selection of a Safe Operational Configuration; Collisions with Small Debris

23. *Background.* In the *Orbital Debris Notice*, the Commission observed that the U.S. Government Standard Practices include two provisions that speak directly to the hardware design of spacecraft. First, the U.S. Government Standard Practices require that programs assess and limit the amount of orbital debris released in a planned manner during normal operations.<sup>75</sup> Concerning this element of debris mitigation, the *Notice* observed that communications payloads approved by the FCC do not typically involve the planned release of any operational debris during normal operations.<sup>76</sup> As a result, the *Notice* proposed that parties submitting an orbital debris mitigation showing simply confirm that there will not be any planned release of operational debris during normal operations of the space station.<sup>77</sup> Second, the U.S. Government Standard Practices require that programs select a safe operational configuration. In order to address this element of debris mitigation, a program must assess and limit the probability that an operating space station will become a source of orbital debris through collisions with debris smaller than one centimeter in diameter that will cause loss of control and prevent post-mission disposal. This element of debris mitigation practices implicates hardware design insofar as it involves shielding of spacecraft components, placement of components, and the use of redundant systems. The *Notice* suggested that to address this element of debris mitigation, applicants could simply confirm that they have assessed the possibility of such collisions and have taken steps to limit their effects.<sup>78</sup>

24. *Discussion.* We adopt the proposals of the *Orbital Debris Notice* regarding disclosure of debris released during normal operations and efforts made to limit the probability that an operating space station will become a source of orbital debris through collisions with small debris that cause loss of control and prevent post-mission disposal. First, the record supports the observation that communications space stations do not typically involve the planned release of orbital debris. Comments confirm that very little, if any, orbital debris is produced by communication satellites as part of normal operations.<sup>79</sup> SIA states that upon the successful separation of the spacecraft from the launch vehicle and deployment, the spacecraft stays in one piece throughout its useful life and disposal process, absent a catastrophic event

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<sup>73</sup> 47 C.F.R. § 25.117.

<sup>74</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5598.

<sup>75</sup> *Id.* at 5601.

<sup>76</sup> *Id.*

<sup>77</sup> *Id.*

<sup>78</sup> *Id.*

<sup>79</sup> SIA Comments at 6; Telesat Comments at 4.

such as a collision with a man-made object or meteor.<sup>80</sup> We conclude that a statement confirming that no debris will be released by the space station during normal operations will be sufficient to meet disclosure obligations. In any instances where release of operational debris is planned, we will examine such plans on a case-by-case basis and retain the discretion to seek additional information or to take action, through conditioning or denying approval, in the event that we find that such release will not serve the public interest.

25. We also conclude that confirmation as part of a debris mitigation disclosure that the satellite system operator has considered possible collisions with small debris and taken steps to limit the effects of such collisions, such as through shielding, the placement of components, and the use of redundant systems, will generally be considered sufficient, in the absence of specific facts suggesting the contrary, to satisfy disclosure obligations. We do not anticipate that this disclosure requirement will prove burdensome for the majority of systems, since satellite operators assert that they already assess the probability of such collisions in orbit and take steps to limit the effects of such collisions.<sup>81</sup> For example, Telesat confirms that it requires system redundancy as part of its satellite procurement process and that it requires that single point failures within a satellite to be minimized or eliminated, so that the adverse impact of such failures can be minimized to the maximum extent possible.<sup>82</sup>

26. We are not persuaded by comments that argue either for more detailed Commission regulation regarding the operational configuration of space stations or for no Commission regulation whatsoever. UM Space Law Center argues that space station operators may have an economic incentive to omit hardening or shielding of a satellite structure due to the additional cost of such efforts and because the resulting "weight penalty" could reduce the amount of on-board revenue-generating payload.<sup>83</sup> Accordingly, UM Space Law Center urges us to adopt guidelines for space station design and to require operators to submit a cost-benefit analysis that weighs the benefits of various forms of debris mitigation that can be incorporated in a satellite design versus the costs related to each of those forms.<sup>84</sup> By contrast, SIA claims that it is not useful to have any confirmation that an operator has assessed the probability a spacecraft would become a source of orbital debris through collisions, since the Commission does not propose to set standards for the evaluation of such assessments and because the Commission has traditionally left space station design issues to the operator.<sup>85</sup>

27. We agree with commenters that it is unlikely that a satellite operator would trim satellite construction costs by electing to omit hardening or shielding of a spacecraft, when such an action would expose the operator to significant risk of loss of the entire revenue-producing payload of that satellite.<sup>86</sup> Given the economic self-interest of satellite operators in protecting revenue-producing operations from damage through in-orbit collisions, and given our understanding that the systems used in a typical communications satellite for mission operations are the same as those used for end-of-life disposal, we believe more detailed disclosure requirements are unlikely to yield any significant benefit to the regulatory process. However, if the spacecraft design involves use of a sub-system or set of sub-systems,

<sup>80</sup> SIA Comments at 6.

<sup>81</sup> SIA Comments at 6; Telesat Comments at 4.

<sup>82</sup> Telesat Comments at 3-4.

<sup>83</sup> UM Space Law Center Comments at 2.

<sup>84</sup> *Id.*

<sup>85</sup> SIA Comments at 6-7 (citing *Amendment of the Commission's Rules to Establish Rules and Policies Pertaining to a Mobile-Satellite Service in the 1610-1626.5/2483.5-2500 MHz Frequency Bands*, Notice of Proposed Rulemaking, 9 FCC Rcd 1094 (1994))(Big LEO NPRM)). See also SES Americom Reply at 4.

<sup>86</sup> Telesat Reply at 4; SES Americom Reply at 4.

distinct from systems used in connection with the primary communications mission, in order to accomplish end-of-life disposal, an applicant's disclosure should address in greater detail the measures taken specifically to analyze the susceptibility of that sub-system to collisions with small debris.

28. We disagree, however, that requiring confirmation that a space station operator has assessed and limited the probability that its spacecraft would be unable to perform end-of-life maneuvers as a result of collisions with small debris serves no useful purpose unless the Commission adopts set standards for the review of such assessments. Although we anticipate that the majority of satellite operators have an economic incentive to design their spacecraft as robustly as possible in order to protect revenue-producing operations, this may not always be true. For example, the record indicates that satellite system designs are emerging that involve large constellations of ultra-small satellites in which the redundancy permitted by a large number of satellites permits the reliability of any individual satellite in the constellation to be low without impacting the reliability of the constellation as a whole.<sup>87</sup> By requiring confirmation that a space station operator has taken measures to ensure a safe operational configuration of its satellite system through hardware design, we preserve the ability to take action, through conditioning an authorization or denying an application in those instances where economic incentives may not be sufficient by themselves to ensure that the applicant has adequately taken debris mitigation into account during the design of its spacecraft. Although our preference is to leave spacecraft design decisions to space station operators, this preference does not foreclose the Commission from considering design issues insofar as they may impact the public interest.

## 2. Minimizing Debris Generated by Accidental Explosions

29. *Background.* The prevention of accidental explosions during and after completion of mission operations constitutes perhaps the single most important debris mitigation measure in preventing potential damage to space assets.<sup>88</sup> Explosions in space can produce a large number of debris fragments dispersed over a much wider range of orbits than the orbit of the exploded object.<sup>89</sup> Indeed, it is estimated that fragmentation debris accounts for more than 40 percent of the catalogued orbital debris population, and that the vast majority of this fragmentation debris has been created by the explosive breakups of spacecraft and rocket bodies.<sup>90</sup>

30. For these reasons, the *Orbital Debris Notice* proposed to require confirmation in orbital debris mitigation disclosures that space station operators have assessed and limited the probability of accidental explosions during and after completion of mission operations. The *Notice* proposed specifically that applicants demonstrate that "debris generation will not result from the conversion of energy sources on board the spacecraft into energy that fragments the spacecraft," and that such a demonstration should specifically address measures taken at the spacecraft's end of life.<sup>91</sup> These requirements are similar to a rule adopted by the Federal Aviation Administration (FAA) for launch vehicle upper stages.<sup>92</sup> The *Notice* tentatively concluded that satellite operators' self-interest in ensuring

<sup>87</sup> See *Ecliptic Comments* at 7.

<sup>88</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5602.

<sup>89</sup> For a more detailed discussion of explosions and other satellite fragmentation events, see History of On-Orbit Satellite Fragmentations, available on-line at <http://www.orbitaldebris.jsc.nasa.gov>.

<sup>90</sup> *Orbital Debris: A Technical Assessment* at 138; *STSC Technical Report on Orbital Debris* at 32 (para. 98).

<sup>91</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5602.

<sup>92</sup> *Id.* at 5602-03. The FAA regulation, codified at 14 C.F.R. § 415.39, reads:

To obtain safety approval, an applicant must demonstrate for any proposed launch that for all launch vehicle stages or components that reach earth orbit –

spacecraft reliability provides incentive to design a spacecraft that does not experience accidental explosions during its useful life, but questioned whether operators have similar incentive at or near the end of a spacecraft's life, since an operator may have the economic incentive to continue income-producing activities even as a spacecraft's systems degrade.<sup>93</sup>

31. *Discussion.* We adopt the proposal of the *Orbital Debris Notice* to require confirmation in orbital debris mitigation disclosures that space station operators have assessed and limited the probability of accidental explosions during and after completion of mission operations. Because of the particular danger that accidental explosions pose to safe and reliable operations, we conclude that requiring confirmation that space station operators have assessed and limited the risk of accidental explosions serves the public interest.

32. Such a disclosure requirement should be sufficient in most cases to serve the public interest. Comments support the tentative conclusion of the *Notice* that satellite operators' self-interest provides adequate incentive for the majority of operators to design spacecraft that do not experience accidental explosions during useful life.<sup>94</sup> Although we agree that many satellite operators address the risk of accidental explosions throughout the life span of the satellite, it does not follow, as some commenters suggest,<sup>95</sup> that disclosure of such assessment to the Commission is not useful. Given the significance of this issue for growth of the debris population, we think the limited disclosure we are seeking is justified. In addition, there may be situations where economic incentives, by themselves, are insufficient to ensure that the risk of accidental explosions is adequately addressed. For example, it may be the case that non-commercial operators do not have the same economic incentives to ensure reliability as commercial operators, since the financing of their activities may have little to do with the ability of the spacecraft to continue revenue-producing activity. Thus, given the serious consequences of accidental explosions of spacecraft in orbit, we believe that the public interest would be served by ensuring space station applicants have assessed and limited the probability of such explosions.

33. Such disclosure should not be burdensome. Comments indicate that satellite operators already consider the possibility of accidental explosions and should not experience difficulty in confirming that they have assessed and limited the probability of accidental explosions as part of their

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(a) There will be no unplanned physical contact between the vehicle or its components and the payload after payload separation;

(b) Debris generation will not result from the conversion of energy sources into energy that fragments the vehicle or its components. Energy sources include chemical, pressure, and kinetic energy; and

(c) Stored energy will be removed by depleting residual fuel and leaving all fuel line valves open, venting any pressurized system, leaving all batteries in a permanent discharge state, and removing any remaining source of stored energy. Other equivalent procedures may be approved in the course of the licensing process.

<sup>93</sup> *Id.* at 5602.

<sup>94</sup> SIA states that operators already routinely conduct a failure mode verification analysis (FMVA) as part of the satellite design review to ensure that failure of a component aboard the satellite does not lead to an accidental explosion. See SIA Comments at 9. Furthermore, Telesat claims that satellite operators have economic incentive to design spacecraft that do not experience accidental explosions during or after mission operations so that the spacecraft does not threaten the ability of the operator to operate a replacement satellite at the same orbital position, or to use an aging satellite as an on-orbit spare or to lease the satellite to a third-party near the end of life. See Telesat Comments at 5.

<sup>95</sup> SIA Comments at 9.

orbital debris mitigation disclosure.<sup>96</sup> Indeed, one operator expressly states that it would not be onerous to require operators to confirm expressly in their debris mitigation disclosures that they have assessed and limited the risk of accidental explosions.<sup>97</sup> Accordingly, we amend our rules as proposed in the *Notice* to require a statement, as part of the debris mitigation disclosure, that a space station operator has assessed and limited the probability of accidental explosions during and after mission operations.<sup>98</sup> In the event that a showing suggests that further review may be warranted, we retain the discretion to seek additional information from the applicant and preserve the ability to take action, through conditioning an authorization or denying an application in those instances where economic incentives may not be sufficient by themselves to ensure that the applicant has adequately assessed and limited the risk of accidental explosions.

### 3. Safe Flight Profiles: Collisions With Large Objects

34. The U.S. Government Standard Practices provide that programs and projects will select safe flight profiles by assessing and limiting the probability of operating space systems becoming the source of debris by collisions with man-made objects or meteoroids.<sup>99</sup> More specifically, the guidelines provide that, when developing the design and mission profile for a spacecraft, a program will estimate and limit the probability of collision with known large objects during orbital lifetime. The *Notice* observed that while current Commission rules and international regulations have several provisions that impact the selection of the flight profile for a satellite, those rules and regulations were developed primarily to address radiofrequency interference concerns. Thus, for example such rules may not by themselves adequately address situations where functioning satellites operate in different frequency bands, but are located in similar orbits, such as the same GEO satellite orbit location. The *Notice* observed, however, that an applicant's disclosure in the licensing process of, for example, the parameters of the orbits its system would use, may assist third parties in identifying potential problems that may be caused by the proposed operations. It noted that in the most heavily used orbits, or in orbits with particularly sensitive operations, such as orbits used for manned space flight, additional measures may be warranted to avoid collision, such as coordination among the operators, or assignment of orbital locations designed to ensure adequate physical separation between operational satellites.<sup>100</sup> It also inquired whether any changes were needed to our existing rules and practices in light of these considerations. We discuss below our existing rules and changes proposed by commenters as they relate to four phases of space station authorization and operations: the application filing; pre-operational phase; on-orbit operations; and coordination of maneuvers.

#### a. Application Information Requirements

35. *Background.* Applicants seeking a space station authorization must submit technical information regarding the proposed space station as set forth in Section 25.114 of the Commission's

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<sup>96</sup> SIA Comments at 9; Telesat Comments at 5.

<sup>97</sup> Telesat Comments at 6.

<sup>98</sup> SIA states that satellite operators and manufacturers treat their failure mode verification analyses as confidential business information, and implies that our disclosure requirement threatens the confidentiality of such analyses. See SIA Comments at 9. Since we do not anticipate requiring applicants to submit those analyses in the ordinary course, but rather simply to confirm that such an analysis has been undertaken, we do not anticipate that this will be a routine issue. In the event such a submission is required, our rules provide protections for any documents that warrant confidential treatment. See 47 C.F.R. § 0.459.

<sup>99</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5603.

<sup>100</sup> *Id.*

rules.<sup>101</sup> This information includes the physical characteristics of the space station,<sup>102</sup> the satellite's orbital location and the factors that went into selection of that location,<sup>103</sup> the accuracy with which a GEO satellite's orbital inclination and longitudinal drift will be maintained,<sup>104</sup> and, for non-GEO satellite systems, the number of space stations in the system, the inclination of the orbital plane(s), orbital period, apogee, perigee, the argument(s) of perigee, active service arc(s), and right ascension of the ascending node(s).<sup>105</sup> The *Notice* inquired whether the information required to be submitted under Section 25.114 provides an adequate basis for potentially affected parties to evaluate proposed systems with respect to collision avoidance and safe flight profiles.<sup>106</sup> Furthermore, it sought comment on whether Section 25.114 should be amended to require non-geostationary satellites systems to disclose the accuracy with which they will maintain orbital parameters such as apogee, perigee, period, and inclination.<sup>107</sup>

36. *Discussion.* We conclude that the information requirements of Section 25.114, as amended today, are sufficient with respect to collision avoidance and safe flight profiles and to identify any potential issues with a proposed system that might require further evaluation or action. Comments broadly support this conclusion.<sup>108</sup> We conclude that other alternatives proposed by commenters would not necessarily meet the same goals.<sup>109</sup>

<sup>101</sup> 47 C.F.R. § 25.114. Subsequent to the release of the *Orbital Debris Notice*, Section 25.114 was substantially amended as a result of our adoption of a standardized form for space station license applications. See *Amendment of the Commission's Space Station Licensing Rules and Policies, 2000 Biennial Regulatory Review – Streamlining and Other Revisions of Part 25 of the Commission's Rules Governing the Licensing of, and Spectrum Usage by, Satellite Network Earth Stations and Space Stations*, Third Report and Order and Second Further Notice of Proposed Rulemaking, IB Docket Nos. 02-34 and 00-248, FCC 03-154, 18 FCC Rcd 13486 (2003) (*Space Station Licensing Third Report and Order*). As a result, the subsection numbers referenced in this Second Report and Order may differ from the numbers referenced in the *Notice*.

<sup>102</sup> 47 C.F.R. § 25.114(c)(10).

<sup>103</sup> 47 C.F.R. § 25.114(c)(5).

<sup>104</sup> 47 C.F.R. § 25.114(c)(5)(iii) and (5)(iv). As noted in the *Orbital Debris Notice*, without so-called “north-south” station-keeping, the inclination of a GEO satellite will gradually increase from zero degrees (equatorial orbit) to a maximum of approximately 14.6 degrees. See *Orbital Debris Notice*, 17 FCC Rcd at 5603 n.84. In addition to maintaining the accuracy of its inclination, a GEO satellite must execute station-keeping maneuvers to maintain longitudinal accuracy in order to prevent a naturally occurring drift to the east or to the west due to small variations in the Earth's gravity, unless the spacecraft is located at one of the two “gravity wells” on the geostationary arc. See *id.* at 5604 n.85.

<sup>105</sup> 47 C.F.R. § 25.114(c)(6).

<sup>106</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5604.

<sup>107</sup> *Id.*

<sup>108</sup> SIA Comments at 10 (current information is sufficient to enable operators to evaluate the potential for collisions and safe-flight profiles); Ecliptic Comments at 7-8 (FCC rules requiring applicants to provide orbital information are generally helpful in minimizing the probability of collisions).

<sup>109</sup> SIA refers to a proposal raised in another FCC rulemaking proceeding, in which it proposed that we amend our licensing rules to require applicants to submit only the technical information required by ITU Appendix 4, which sets forth the technical characteristics of a satellite network that must be submitted to the ITU for advance publication and the initiating of coordination of satellite networks. See SIA Comments at 10. SIA argues that this information would also be sufficient to determine safe-flight profiles because the technical information submitted pursuant to Appendix 4 includes, among other things, the orbital characteristics of the satellite network. We have, however, already considered and rejected SIA's proposal in our *Space Station Licensing Rules and Policies* proceeding. See *Space Station Licensing Third Report and Order*, 18 FCC Rcd at 13491 (observing that reliance on ITU submissions alone does not serve the public interest, because the Commission's technical and regulatory (continued....)

37. We also find that the public interest would be served by requiring NGSO systems to disclose, as part of an orbital debris mitigation statement, the accuracy with which orbital parameters will be maintained. This information is already required for GEO systems under Section 25.114(c)(7) of our rules, and we expect that disclosure of this information for NGSO systems will help interested third parties evaluate proposed systems with respect to collision avoidance and safe-flight profiles. In the event that an NGSO system is not able to maintain orbital tolerances, *i.e.*, it lacks a propulsion system for orbital maintenance, that fact should be included in the debris mitigation disclosure. Such systems must also indicate the anticipated evolution over time of the orbit of the proposed satellite or satellites, in order to permit third parties to evaluate the system with respect to collision avoidance and safe flight profiles.

**b. Pre-Operational Phase**

38. *Background.* As observed in the *Orbital Debris Notice*,<sup>110</sup> there may be a substantial period of deployment and testing after a satellite separates from a launch vehicle, but before it commences full commercial operations. During this time, the satellite may operate at a location other than its permanently assigned orbit. The Commission has historically reviewed such operations on a case-by-case basis, either through a request for deployment and testing as part of an applicant's application for authority for "full" operations, or through a request for special temporary authority (STA) filed closer to the time of launch of the satellite system.<sup>111</sup> The *Notice* proposed to continue this general practice, noting that this approach gave the Commission regulatory flexibility in addressing the deployment and testing phase of satellite operations. It observed that many activities in the pre-operational phase are highly transitory in nature, often involving a series of spacecraft maneuvers, and, therefore, it may be difficult to specify precise orbital parameters for those operations. It indicated, however, that when pre-operational activities involve the use of a particular orbit for an extended period of time, the Commission would generally expect licensees to specify precise orbital parameters in their requests for authorization, in a manner consistent with the disclosure requirements in connection with "normal" operations.<sup>112</sup>

39. *Discussion.* We will continue our practice of reviewing pre-operational activities on a case-by-case basis, either through a request for deployment and testing as part of an applicant's application for authority for "full" operations, or through a STA request filed closer to the time of launch of the satellite system. Comments support this proposal,<sup>113</sup> and we believe that this practice provides regulatory flexibility to operators without compromising the Commission's ability to examine whether the public interest is served by the grant of an authorization. Applicants must specify, in a manner consistent with the disclosure requirements of a normal application, the precise parameters of any pre-operational orbits that are intended to be used for an extended period.<sup>114</sup> Applicants must also, wherever possible, include any such orbits in their applications for full operational authority, in order to ensure that any issues concerning the pre-operational phase can be identified at an early stage. We believe this may be of

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requirements are not the same as the ITU requirements and because there is no guarantee that ITU rules will be adequate for U.S. operations). As a result, SIA's proposal is moot and need not be considered here.

<sup>110</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5604.

<sup>111</sup> *Id.*

<sup>112</sup> *Id.*

<sup>113</sup> SIA Comments at 10.

<sup>114</sup> Examples of extended pre-operational activities include the use of a geostationary satellite orbital location for in-orbit testing that is different from the one authorized for use by the satellite operator, or the use of an "engineering" orbit by an NGSO satellite in which satellites are tested and maintained prior to deployment in "mission" orbits. See *Orbital Debris Notice*, 17 FCC Rcd at 5605.

particular importance for NGSO systems that will seek to use “engineering” or “parking” orbits for satellites not involved in full system operations.

40. With respect to the types of transitory operations involved in “orbit-raising”<sup>115</sup> and similar maneuvers in the pre-operational phase, we are adopting a new rule, Section 25.282, to make clear that, although such operations are of necessity at variance with the orbital parameters specified in the license for “full” operations, they are nonetheless authorized operations, provided they meet certain conditions designed to avoid radio-frequency interference.<sup>116</sup>

### c. On-Orbit Operations

41. *Background.* Currently, very few Commission rules exist that govern the physical aspects of the on-orbit operations of space stations. Furthermore, existing rules were designed with radiofrequency interference in mind, rather than debris mitigation. The *Orbital Debris Notice* examined the Commission’s existing rules, proposed several amendments and additions, and sought comment on several additional issues that might require rule changes. We discuss each of these matters below.

42. *Discussion.* First, the *Notice* observed that Section 25.210(j) of the Commission’s rules specifies that fixed-satellite service satellites in geostationary orbit must be designed with the capability of being maintained in orbit within  $\pm 0.05^\circ$  of their assigned orbital longitude, and must be maintained in orbit at their assigned orbital longitude with the longitudinal tolerance specified by the Commission.<sup>117</sup> As noted in the *Notice*, this rule parallels, but is generally more stringent than, the requirement in the ITU Radio Regulations, which requires geostationary FSS and broadcast satellite service (BSS) satellites to maintain their positions within  $0.1^\circ$  of their assigned positions.<sup>118</sup> Because a geostationary satellite in the process of removal from orbit at the end of its mission would not comply with this rule, we proposed to amend the language of Section 25.210(j) to provide an explicit exception for such operations. In addition, we proposed to shorten and simplify the text of the rule and sought comment whether to apply the  $\pm 0.05^\circ$  longitudinal tolerance applicable to fixed-satellite service space stations to space stations in other services.<sup>119</sup> In this regard, we noted that longitudinal tolerance is much less important to radio-frequency interference for remote sensing and mobile-satellite systems at GEO than for fixed-satellite services.<sup>120</sup>

43. We adopt the changes to the text of Section 25.210(j) that were proposed in the *Notice* to shorten and simplify the text of the rule and to provide an explicit exception for certain end-of-life operations. Comments received in response to these proposals generally support these suggested changes. SIA favors the simplification of the text of Section 25.210(j) and welcomes the explicit exception to the  $\pm 0.05^\circ$  longitudinal tolerance requirement in the case of post-mission disposal operations.<sup>121</sup> SIA also

<sup>115</sup> As used in this Second Report and Order, “orbit raising” refers to the process by which a satellite is maneuvered after launch typically from a lower initial orbit into a higher permanent operational orbit.

<sup>116</sup> See Appendix B.

<sup>117</sup> 47 C.F.R. § 25.210(j).

<sup>118</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5605.

<sup>119</sup> *Id.* (seeking comment on applicability of FSS longitudinal tolerance to other services, such as mobile-satellite service or remote sensing satellites); see *id.* at n.89 (noting that the rules for DBS, which at the time of the release of the *Orbital Debris Notice* were contained in Part 100 of the Commission’s rules, were in the process of being consolidated into Part 25). Since release of the *Notice*, the rules for DBS have been consolidated into Part 25. See *Policies and Rules for the Direct Broadcast Satellite Service*, Report and Order, IB Docket No. 98-21, FCC 02-110, 17 FCC Rcd 11331 (2002).

<sup>120</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5606 n.92.

<sup>121</sup> SIA Comments at 11.

indicates that satellite operators would be able to comply with the simplified text of Section 25.210(j), since it claims that it is already industry practice to maintain GEO satellites within  $\pm 0.05^\circ$  of their assigned orbital longitude, unless otherwise authorized by the Commission.<sup>122</sup> Other comments state that GEO satellite operators are generally conscientious about staying within their assigned longitudinal bands, although errors can inadvertently occur from time to time due to faulty calibration of the transponder ranging data that is used to determine the orbits and longitude of the satellite.<sup>123</sup>

44. We decline, at this time, to adopt changes to Section 25.210(j) to specify a longitudinal tolerance of  $\pm 0.05^\circ$  for all space stations, including MSS and remote sensing space stations. Although one commenter observes that precise station-keeping requirements are important so that adjacent or co-located satellite operators know that neighboring satellites have control requirements and will not encroach into an adjoining station-keeping box, this commenter does not necessarily support adopting a  $\pm 0.05^\circ$  longitudinal tolerance requirement for all GEO space stations.<sup>124</sup> Other parties, chiefly proponents of MSS systems, argue that a  $\pm 0.05^\circ$  longitudinal tolerance is unnecessary and economically burdensome for MSS systems, particularly those operating in highly inclined orbits.<sup>125</sup> In addition, FSS operators observe that MSS spacecraft frequently use FSS frequency bands for feeder links and for tracking, telemetry, and control operations and express concern that, if MSS satellites are allowed a larger station keeping tolerance than the  $\pm 0.05^\circ$  tolerance required for FSS systems, the MSS operations could cause operational restrictions or radiofrequency interference to adjacent or co-located FSS spacecraft.<sup>126</sup> We conclude that the record in this proceeding is not sufficiently developed at this time to adopt a change in our rules with respect to non-FSS space stations, and that the radiofrequency interference concerns specified by FSS operators raise issues that need additional exploration in a further notice of proposed rulemaking in this proceeding. Accordingly, we defer this issue to a further notice of proposed rulemaking to be initiated at a later date. Our action today does not, however, alter in any way the obligation of space stations in the Fixed-Satellite Service to comply with the  $\pm 0.05^\circ$  longitudinal tolerance requirements of Section 25.210(j), as amended herein.

45. The second change proposed in the *Orbital Debris Notice* involved amending the text of Section 25.280 of the Commission's rules.<sup>127</sup> Section 25.280 permits satellite operators in

<sup>122</sup> SLA Comments at 11.

<sup>123</sup> MIT Lincoln Laboratories Comments at 2.

<sup>124</sup> Telesat Comments at 7.

<sup>125</sup> See, e.g., Letter from Bruce Olcott, Counsel for The Boeing Company, to Marlene Dortch, Secretary, FCC, dated December 23, 2003; Letter from Alexander Hoehn-Saric, Counsel for Inmarsat Ventures Ltd., to Marlene Dortch, Secretary, FCC, dated December 23, 2003; Letter from John Janka, Counsel for Inmarsat Ventures Ltd., to Marlene Dortch, Secretary, FCC, dated January 9, 2004; Letter from John Janka, Counsel for Inmarsat Ventures Ltd., to Marlene Dortch, Secretary, FCC, dated January 16, 2004; Letter from Christian Pietrowski, VP - Telecommunications Marketing & Sales, EADS Astrium, to Marlene Dortch, Secretary, FCC, dated March 8, 2004.

<sup>126</sup> See Letter from Kalpak Gude, Vice President of Government and Regulatory Affairs and Associate General Counsel, PanAmSat Corp., et al. to the Hon. Michael Powell, Chairman, FCC, dated January 13, 2004 (FSS Operators January 13 Ex Parte) at 1. In reply, Boeing asserts that MSS spacecraft are unlikely to cause radiofrequency interference to FSS systems, arguing that co-located FSS and MSS systems are generally not authorized to operate in the same frequency bands and, in any event, that the relatively low transmit power and large gateway earth stations used by MSS systems makes it unlikely that MSS transmissions would interfere with FSS operations. See Letter from Bruce Olcott, Counsel for The Boeing Company, to Marlene Dortch, Secretary, FCC, dated January 22, 2004 at 2.

<sup>127</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5606.

geosynchronous orbits to operate in inclined orbits<sup>128</sup> without prior Commission authorization, subject to certain conditions, including notification to the Commission of such operations.<sup>129</sup> The *Notice* proposed to amend the text of this rule by specifying that notification to the Commission must occur within 30 days after the last north-south station-keeping maneuver, and by requiring that this notification include a description of the post-mission disposal plans for the spacecraft.<sup>130</sup> SIA supports our proposal as a welcome clarification of the rule's notification obligation.<sup>131</sup> Accordingly, we adopt the proposed changes to Section 25.280.

46. The *Notice* also sought comment on whether to specify a required tolerance, akin to the GEO station-keeping rule, concerning maintenance of orbits for non-geostationary satellite systems, or whether the public interest would be better served by addressing tolerances for NGSO systems on a case-by-case basis.<sup>132</sup> Although we believe a disclosure requirement concerning the tolerance within which an NGSO orbit will be maintained is warranted, we decline to specify at this time any tolerances that NGSO satellite systems must meet as a precondition to licensing. We agree with commenters who observe that the additional number of orbital parameters that NGSO satellite systems have to work with as compared to GEO space stations makes such a tolerance requirement unnecessary,<sup>133</sup> and, as a result, NGSO systems that are not currently equipped with propulsion systems would suffer economic harm out of proportion to the public benefit gained by such a tolerance requirement.<sup>134</sup>

47. Nonetheless, we believe that disclosure of the tolerance to which proposed NGSO systems will maintain their orbits will provide useful information concerning such systems. In the absence of such information, potentially affected parties may find it difficult to evaluate proposed systems and to identify potential issues. For example, the number of parties potentially affected by a proposed system, and the nature of potential concerns, are quite different if a satellite proposed for a "nominal" circular orbit with an altitude of 800 kilometers will be maintained to within 10 kilometers of that orbit, or within 200 kilometers. We retain discretion in any specific case, based upon any concerns arising in the licensing process, to include any needed conditions concerning the tolerance within which an NGSO spacecraft maintains its orbit.

48. The *Notice* also sought comment on limiting the probability of collisions through selection of an operating orbit, such that the operating orbit does not coincide too frequently with the orbit or orbits of other large known objects.<sup>135</sup> Although the *Notice* anticipated that this objective would be readily attainable for the majority of applicants, due to the currently extremely low spatial density of and risk of collision with large debris objects, it sought comment on whether more detailed discussion of potential

<sup>128</sup> That is, the space station will operate without "north-south" station-keeping maneuvers that correct for solar and lunar gravitational forces. Absent such maneuvers, the inclination of a GEO satellite will gradually increase from zero degrees (equatorial orbit) to a maximum of approximately 14.6 degrees.

<sup>129</sup> 47 C.F.R. § 25.280. These conditions are intended to ensure that a satellite operating in an inclined orbit causes no more radio frequency interference to adjacent satellites than would be the case of a satellite operating without an inclined orbit.

<sup>130</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5606 and Appendix B (Proposed Rule Changes).

<sup>131</sup> SIA Comments at 11.

<sup>132</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5606.

<sup>133</sup> SIA Comments at 12 (observing that, unlike GEO space stations that are separated only by longitudinal separation, NGSO satellite systems are separated by multiple orbital parameters, such as orbital altitude, period, and inclination).

<sup>134</sup> *Ecliptic Comments* at 9; *Leggett Comments* at 4; *AMSAT Comments* at 8.

<sup>135</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5606.

collisions may be warranted in specific cases, such as multiple LEO operators seeking to use identical or very similar orbits at the same altitude.<sup>136</sup> The *Notice* proposed, however, to maintain the general policy of leaving the choice of orbital regime and of the specific orbital parameters for any particular system to the discretion of the operator, absent conflicting requests.

49. We continue to believe that, as regards to potential collisions with large objects, the choice of orbit regime and specific orbital parameters is best left to the discretion of the operator in the majority of cases. We conclude that in the majority of instances operators will be able to achieve the objective of selecting an operating orbit that does not coincide too frequently with the orbit or orbits of other large known objects. SIA states that satellite operators already evaluate collision possibilities as part of their due diligence prior to seeking a license or launching a satellite.<sup>137</sup> Satellite operators indicate that, once a satellite is launched, they use the services of entities that can warn geostationary satellite operators of orbital debris and other objects that may enter the orbit of the spacecraft.<sup>138</sup>

50. We conclude, however, that in some instances the public interest would be served by a more detailed discussion of how an operator will avoid potential collisions. The first of these instances, as described in the *Notice*, is where a system will be launched into a low-Earth orbit that is identical, or very similar, to an orbit used by other systems.<sup>139</sup> In such an instance we believe that the operator should submit, as part of its debris mitigation disclosure, an analysis of the potential risk of collision between the LEO systems and a description of what measures the operator plans to take to avoid in-orbit collisions. If the operator is relying on coordination with another system, the operator should indicate what steps have been taken to contact, and to ascertain the likelihood of successful coordination of physical operations with, the other system.

51. The second instance involves proposals to co-locate multiple satellites at a single GEO orbital location. Any entity requesting an assignment of a GEO orbital location must assess whether there are any known satellites located at, or reasonably expected to be located at, the requested orbital location, or assigned in the vicinity of that location such that the station keeping volumes of the respective satellites might overlap. If so, the entity's orbital debris mitigation statement must include a statement as to the identities of those parties and the measures that will be taken to prevent collisions.<sup>140</sup> We observe that there are a number of cases in which operators have successfully located multiple satellites at a single location, and within the same station-keeping volume. These arrangements require real-time coordination. Where the satellites are not operated by a single company, such coordination may present logistical or cost considerations that render it undesirable as a first choice for preventing collisions. Furthermore, in cases where operators coordinate operations, it is particularly important that they use common methods of calibrating measurement of satellite positions, or rely on a third party to provide that service. In general, we will require entities that indicate that they plan to rely on coordination with other operators at the same orbital location to disclose the manner in which that coordination will be effected.

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<sup>136</sup> *Id.* at 5606-07.

<sup>137</sup> SIA Comments at 12.

<sup>138</sup> SIA Comments at 12-13; Telesat Comments at 14.

<sup>139</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5607.

<sup>140</sup> This statement should address any licensed FCC systems, or any systems applied for and under consideration. The statement need not address every filing with the ITU that meets these criteria. The operator should, however, assess and address any systems reflected in ITU filings that are in operation or that it believes may be progressing toward launch, for example, by the appearance of the system on a launch vehicle manifest.

d. Coordination of Maneuvers

52. *Background.* The *Orbital Debris Notice* sought comment on what, if any, notification requirements should be adopted concerning maneuvers by FCC-licensed satellite systems.<sup>141</sup> The *Notice* observed that coordination of such maneuvers may be especially important in connection with certain types of space assets, such as manned spacecraft, and that space objects that are maneuvering may be less predictable in their behavior, which may increase the difficulty in assessing the potential collision risk. The *Notice* observed that the Commission currently does not have a formal coordination or notification process for such maneuvers, but that a number of U.S.-licensed space station operators have in the past exchanged information related to maneuvers informally with potentially affected operators and the U.S. Strategic Command.<sup>142</sup> It sought comment on whether such informal coordination was common and whether, with increases in space activities by an increasing number of operators, a more formal requirement is necessary. It also sought comment on the scope of such a coordination requirement, the parties that should be included in the notification, and the form of the notification.<sup>143</sup>

53. *Discussion.* Based on our experience and the comments in response to the *Notice*, we conclude that existing informal notification procedures have been generally effective so far for avoiding radiofrequency interference involving maneuvering space stations. Satellite operators indicate that informal coordination of maneuvers between operators is common<sup>144</sup> and that this coordination includes coordination with U.S. Strategic Command when appropriate.<sup>145</sup> SIA states that, although the number of operating satellites has increased during recent years, the total number of satellite operators remains relatively small.<sup>146</sup> Accordingly, SIA argues that existing, informal coordination of maneuvers among satellite operators is sufficient and there is no need for additional regulation in this regard.<sup>147</sup> Telesat agrees that it is normal for satellite operators to coordinate informally whenever a GEO space station is maneuvered from its assigned orbital position.<sup>148</sup> Given operators' past practice in coordinating informally during space station maneuvers in order to avoid radiofrequency interference, we conclude that informal coordination can also prove to be effective in minimizing the risks of on-orbit collisions during such maneuvers. Accordingly, we do not adopt formal coordination requirements at this time.

54. We encourage space station operators, however, to engage in coordination discussions with other potentially affected operators whenever they engage in maneuvers that cause a spacecraft to move from an orbit used during normal operations. Absent such discussions, there is an increased risk that a space craft could physically interfere with another space station and contribute additional objects to the debris population.

55. We decline to adopt specific formats for such coordination. In order to ensure that all

<sup>141</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5607.

<sup>142</sup> *Id.*

<sup>143</sup> *Id.*

<sup>144</sup> SIA Comments at 13; Telesat Comments at 7; SES Americom Reply at 4.

<sup>145</sup> SIA Comments at 13; Telesat Comments at 7.

<sup>146</sup> SIA Comments at 13.

<sup>147</sup> *Id.*

<sup>148</sup> Telesat Comments at 7. Telesat indicates that its current practice is to routinely transmit current orbital elements for each of the satellites that it operates to the United States Strategic Command, and, when performing a relocation, to inform all "in-band" operators over the orbital arc in question, and provide those operators with frequency plans and power levels, points of contact, and a summary of the relocation plan.

relevant parties are able to participate in coordination, Telesat proposes the creation of a centralized database of proposed maneuvers, which would be managed by the ITU or some other international agency or group.<sup>149</sup> SES Americom opposes the creation of a centralized database since it believes that existing informal coordination procedures are sufficient without the need for additional regulation.<sup>150</sup> In any event, we are not in a position to consider Telesat's proposal, since it would necessitate action by entities other than the Commission and is beyond our ability to adopt in this proceeding.

56. We decline to adopt a specific rule setting a minimum separation from inhabitable orbiting objects. Although the *Notice* observed that notification of space station maneuvers may be important in connection with certain types of space assets, such as manned spacecraft,<sup>151</sup> the record does not include sufficient information to determine an appropriate minimum separation from inhabitable objects for FCC licensed spacecraft. Entities seeking approval for LEO operations should, however, address such matters in their disclosure statements, including the full range of measures, such as maintaining a minimum distance separation and coordination that will be undertaken to address risks to inhabitable orbiting objects.

57. We also decline to adopt Ecliptic's proposal to require Commission space station licensees to provide to the public the full, classical, Keplerian orbital elements of their spacecraft following launch, and periodically thereafter, in an easily usable format via the FCC website.<sup>152</sup> We find that additional Commission action in this regard is unnecessary. Our existing rules already require NGSO applicants<sup>153</sup> to submit information about their orbits that provides substantially the same information as full, classical Keplerian orbital elements, except for certain information that provides a temporal time frame of reference for the satellite's position in orbit.<sup>154</sup> We do not believe that requiring the submission of more detailed information would, in general, substantially improve the usefulness of data available from the Commission, since an operator undertaking planning requiring such additional information would be well-advised to coordinate directly with any potentially affected satellite systems. In addition, we note

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<sup>149</sup> Telesat Comments at 7-8.

<sup>150</sup> SES Americom Reply at 5.

<sup>151</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5607 n.97 (noting FAA regulations, 14 C.F.R. § 431.43(c), which requires a collision avoidance analysis for reusable launch vehicles in order to maintain at least a 200 kilometer separation from any inhabitable orbiting object).

<sup>152</sup> Ecliptic Comments at 7-8. See also AMSAT Comments at 7-8.

<sup>153</sup> For GEO satellites, the assignment of an orbital location and the station-keeping requirements in our rules necessarily imply a range of Keplerian elements. Thus, Ecliptic's proposal to require periodic reports of this information is not warranted with respect to GEO satellite licensees.

<sup>154</sup> 47 C.F.R. § 25.114(c)(6) (requiring satellites in non-geostationary orbits to file applicable information relating to the number of orbital planes, the inclination of the orbital plane(s), the orbital period, the apogee, the perigee, the argument(s) of perigee, active service arc(s), and right ascension of the ascending node(s)). Classical Keplerian elements include a few elements that are not expressly required by Section 25.114(c): epoch, eccentricity, mean motion, and mean anomaly. Eccentricity can be calculated from the information supplied about the perigee and apogee of the orbit. Likewise, the orbital period can be used to calculate the mean motion, since the period is simply the reciprocal of mean motion. While epoch and mean anomaly require information about the satellite within a frame of reference which is only available after the satellite has been tracked, we note that Schedule S, adopted in the *Space Station Licensing Third Report and Order*, requires NGSO applicants to specify an "orbit epoch date," at the time they file their application. See *Space Station Licensing Third Report and Order*, 18 FCC Rcd at 13542. We recognize that this information does not represent the true epoch; however, the use of a nominal epoch with respect to which satellites in a constellation are referenced facilitates modeling the constellation for radiofrequency and debris mitigation purposes.

that there are a number of public and private sources for such data.<sup>155</sup> Given the availability of this data from other sources, we conclude that it is not necessary to require satellite operators to provide additional information about their orbital parameters other than that already required by our existing rules.

#### 4. Post-Mission Disposal

58. Post-mission disposal consists of measures taken at the end of a spacecraft's useful life that result in removal of the spacecraft from the Earth's orbit or relocation of the spacecraft to a long-term orbit that reduces the risk of interference with operational spacecraft. Effective disposal of non-functional spacecraft not only provides an immediate benefit by protecting operational spacecraft from accidental collisions with orbital debris, but can also have the long-term benefit of reducing the probability of non-functioning objects colliding with one another and creating additional debris in orbits used by functional spacecraft.<sup>156</sup> Although non-functioning rocket bodies and spacecraft comprise only a small fraction of the total orbital debris population, they constitute the majority of its total mass and cross-sectional area. The sizeable cross-sectional area of non-functioning spacecraft presents a large "target area" for orbital debris strikes, and the relatively large mass of these objects could fragment into a large number of smaller debris pieces upon impact with another object.<sup>157</sup> This fragmentation debris could be spread over a large area and could result in a significant increase in the overall orbital debris population.<sup>158</sup>

59. The *Orbital Debris Notice* inquired whether it would be appropriate at this time to adopt post-mission disposal requirements for Commission-licensed spacecraft.<sup>159</sup> The *Notice* observed that the U.S. Government Standard Practices provides for the disposal of spacecraft after completion of mission, subject to considerations of cost-effectiveness, by means of three alternative methods: (1) direct retrieval; (2); atmospheric re-entry; and (3) maneuvering into a storage orbit.<sup>160</sup> We discuss each of these methods in turn.

60. *Direct Retrieval.* The first method of post-mission disposal is direct retrieval of the spacecraft from orbit. Although direct retrieval ensures that an object will not become a source of a large amount of orbital debris in the future, it can be expensive and has generally not been considered to be a cost-effective option of debris mitigation. Furthermore, direct retrieval has only been attempted at low-Earth orbits. The *Notice* noted that direct retrieval currently has limited relevance for post-mission disposal of Commission-licensed space stations.<sup>161</sup>

<sup>155</sup> For example, NASA's Orbital Information Group (OIG) makes available unclassified satellite orbital data that has been received from U.S. Government sources. See *OIG website*, available at <http://oig1.gsfc.nasa.gov/>. In addition, we observe that there are numerous private companies that provide databases of the orbital parameters of objects in Earth orbit.

<sup>156</sup> *Orbital Debris: A Technical Assessment* at 167.

<sup>157</sup> *Id.*

<sup>158</sup> *Id.* at 161.

<sup>159</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5608.

<sup>160</sup> *Id.* at 5607-08.

<sup>161</sup> *Id.* at 5591 n.16. One commenter argues that we should not dismiss direct retrieval as a long-term possibility for post-mission disposal and proposes that we promote an economic incentive in direct retrieval by adopting a rule that allows the salvage of non-functioning U.S.-licensed spacecraft by U.S. nationals. See *UM Space Law Center Comments* at 3. We stress that we did not intend to dismiss or in any way foreclose direct retrieval. If direct retrieval is implemented in the future, we will have the opportunity to revisit this issue at that time. Any such commercial mission would require radio-frequency authorization, and, in connection with any such FCC authorization we will, as a result of the rules adopted in this proceeding, have an opportunity to evaluate public

(continued....)

61. *Atmospheric Re-entry.* Atmospheric re-entry is a disposal process by which a spacecraft is brought into the Earth's atmosphere to disintegrate as a result of friction with the atmosphere. Atmospheric re-entry is typically achieved by one of two procedures. The first entails using the spacecraft's propulsion system (if it is capable of doing so) to propel the spacecraft out of orbit into the Earth's atmosphere. The second is achieved by leaving a spacecraft in an orbit from which the natural phenomenon of atmospheric drag will eventually cause the spacecraft to re-enter the Earth's atmosphere without the use of propulsion systems. If a program or project selects to leave the spacecraft in an orbit from which it will re-enter the Earth's atmosphere without the use of propulsion, the U.S. Government Standard Practices call for the selection of an orbit from which the spacecraft will remain in orbit no longer than 25 years after mission completion.<sup>162</sup> Under the U.S. Government Standard Practices, programs using either procedure must address the human casualty risk from any portions of the spacecraft that may survive atmospheric re-entry.<sup>163</sup> Because of the prohibitively large amounts of fuel that would be required to be stored and expended to lower the spacecraft's altitude into a re-entry orbit, atmospheric re-entry currently is not a feasible alternative for disposal of spacecraft in higher orbits, such as GEO.

62. *Storage Orbit.* A third method of post-mission disposal is maneuvering a spacecraft to a storage or disposal orbit where the spacecraft is unlikely to pose a risk to operational spacecraft in high value orbits.<sup>164</sup> The use of a storage orbit leaves an object in Earth orbit, but removes it from regions where it would pose a direct collision hazard to functional spacecraft.<sup>165</sup> The U.S. Government Standard Practices suggest four potential storage orbits: (1) between low-earth and medium-earth orbit, *i.e.*, satellite perigee altitude above 2000 km and apogee altitude below 19,700 km; (2) between medium-earth orbit and geosynchronous orbit, *i.e.*, perigee altitude above 20,700 km and apogee altitude below 35,300 km (500 km below geosynchronous orbit); (3) above geosynchronous orbit, *i.e.*, a perigee altitude above 36,100 km (300 km above geosynchronous orbit); and (4) removal from Earth orbit into a heliocentric orbit, *i.e.*, the spacecraft is removed to an orbit around the sun.<sup>166</sup>

63. As detailed more fully below, the *Orbital Debris Notice* sought comment on whether to adopt these three methods as requirements for the post-mission disposal of Commission-licensed spacecraft.<sup>167</sup> The *Notice* specifically sought comment on the application of these disposal methods to geostationary and non-geostationary spacecraft. It also sought comment on whether a Commission rule is necessary to ensure that spacecraft reserve adequate fuel to execute post-mission disposal maneuvers, as well as on any other matters that may affect the ability of a spacecraft to execute end-of-life maneuvers reliably.<sup>168</sup> We address each of these issues below.

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interest considerations, including the benefits of removing debris, as well as any possible debris generation, that may result from a direct retrieval mission. Any issues related to salvage that are within the scope of our authority can be addressed at that time.

<sup>162</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5608.

<sup>163</sup> *Id.*

<sup>164</sup> *Id.*

<sup>165</sup> *Orbital Debris: A Technical Assessment* at 148.

<sup>166</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5608.

<sup>167</sup> *Id.*

<sup>168</sup> *Id.* at 5609.

a. GEO Space Stations

64. *Background.* The *Orbital Debris Notice* described developments in recommendations concerning GEO disposal. The ITU adopted a recommendation in 1993, ITU Recommendation S.1003, which recommends that GEO spacecraft be removed at end of life to a disposal orbit with a minimum perigee of 300 kilometers above GEO.<sup>169</sup> The U.S. Government Standard Practices also adopted this standard for disposal of GEO spacecraft. In addition, the *Notice* indicated that the IADC had developed a recommendation concerning GEO satellite disposal. That recommendation provides a formula for calculating a minimum disposal altitude above GEO that takes into account the major physical forces that act upon a spacecraft after the end of its useful life, and the fact that the effect of those forces may vary based on characteristics of the spacecraft. Since the release of the *Notice*, the ITU has revised Recommendation S.1003 to endorse use of the IADC formula for calculating minimum disposal altitudes for GEO spacecraft.<sup>170</sup>

65. The *Orbital Debris Notice* proposed to amend the Commission's rules to provide GEO space station licensees with authority to dispose of space stations at the end of life, without the need for a case-by-case authorization, provided that the disposal plan meets specified criteria.<sup>171</sup> One criterion is that the licensee maneuvers its spacecraft at the end-of-life into a disposal orbit calculated using the IADC formula. This formula is reproduced below:

$$36,021 \text{ km} + (1000 \cdot C_R \cdot A/m)$$

where  $C_R$  is the solar radiation pressure coefficient of the spacecraft, and  $A/m$  is the Area to mass ratio, in square meters per kilogram, of the spacecraft. This formula is based on a GEO altitude of 35,786 kilometers and establishes a "protected region" of 200 kilometers around GEO, plus 35 kilometers to account for the maximum descent of a re-orbited spacecraft due to lunar, solar, and geopotential perturbations. The formula then provides an additional term to take into account the solar radiation pressure on a particular spacecraft.<sup>172</sup> The effects of solar radiation pressure vary, based on the mass of the spacecraft, but generally render the spacecraft's orbit more elliptical. As a result, unless this effect is taken into account in selecting a disposal altitude, it is possible for a spacecraft to drift back into the GEO protected region, or, in some cases, into GEO itself.

66. *Discussion.* We conclude that the public interest would be served by adopting rules for the post-mission disposal of Commission-licensed GEO space stations. Unless GEO spacecraft are disposed of at end of life in an effective manner, decommissioned spacecraft pose a risk to the continued reliable and affordable use of GEO. If disposed of at or near GEO, a decommissioned spacecraft could physically interfere with a functional spacecraft that is being controlled at its assigned longitudinal location at GEO. Even if removed from GEO, a decommissioned spacecraft can present a collision risk to functional

<sup>169</sup> *Id.* at 5608-09. The recommendation suggests, in pertinent part, that a GEO satellite at the end of its life should be transferred before complete exhaustion of its propellant, to a "supersynchronous graveyard orbit that does not intersect the [GEO]," with GEO defined as the mean earth radius of 42,164 kilometers plus or minus 300 kilometers. The recommendation also notes that what constitutes "an effective graveyard orbit" requires further studies. In this regard, we note that orbital perturbations due to solar and lunar gravitation, solar radiation pressure, or other sources, may, over time, result in an inactive satellite's orbit intersecting the GEO, as defined by the ITU recommendation, even if the initial disposal altitude does not intersect the GEO.

<sup>170</sup> See *supra* note 43 and accompanying text.

<sup>171</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5609.

<sup>172</sup> Solar radiation pressure is momentum imparted to the spacecraft by the absorption and re-radiation of the sun's radiation.

spacecraft operating in orbits above GEO as part of a transfer maneuver to change the longitudinal location of that spacecraft.<sup>173</sup> A collision involving a decommissioned satellite, or its fragments, is likely to lead to a degradation or total loss of the telecommunications capabilities of an operational spacecraft and the creation of additional debris fragments. Debris from such a collision will remain on orbit virtually forever. The wide-spread distribution of debris across GEO could result in the degradation of the reliability of GEO satellite communications for the foreseeable future. Even absent such collisions, the increased presence of debris in heavily-used orbits could force operators to incur additional expenses to increase the survivability of their spacecraft through additional shielding or through other measures designed to avoid collision. Such measures to avert the damage caused by collision would add to the cost of spacecraft operations.

67. Although it is difficult to estimate the risk of collision of objects in the geostationary region with any degree of precision,<sup>174</sup> the current risk of collision is considered to be very low due to the relatively low spatial density of debris in the GEO region. For example, a report by the United Nations released in 1999 estimates the annual risk of collision for an average operational satellite with other objects greater than one meter in diameter is  $10^{-5}$ .<sup>175</sup> It is reasonable to assume, however, that the risk of collision will increase in the future. First, we do not anticipate that the population of active spacecraft in GEO is likely to decrease, but rather is likely to remain stable or grow moderately as operators replace decommissioned space stations and launch additional space stations to increase capacity. Second, there is no natural removal mechanism for spacecraft at higher orbital altitudes, and absent disposal maneuvers, objects will remain indefinitely at these altitudes once placed into orbit. As a result, debris will continue to accumulate, and the risk of collision will increase as more functional and non-functional objects are placed in or near GEO. Given the importance of GEO and the serious and potentially irreversible effects that the presence of orbital debris can have in the GEO region, we do not believe the public interest would be served by waiting until the risk to operations in this orbit becomes unacceptably high before taking action.

68. Accordingly, we adopt the proposal of the *Orbital Debris Notice* to evaluate end-of-life plans for GEO space stations according to the formula developed by the IADC for determining the storage altitude for GEO spacecraft at the end of life.<sup>176</sup> We believe that application of this formula provides the best long-term protection to operational GEO spacecraft from orbital debris. Unlike the disposal practices for GEO spacecraft set forth by the U.S. Government Standard Practices, the IADC formula takes into account the specific characteristics of individual spacecraft, such as its susceptibility to the effects of solar radiation pressure, which may cause a spacecraft eventually to drift back into GEO. Furthermore, use of the IADC formula establishes a 200-kilometer "protected region" around GEO that

<sup>173</sup> By increasing altitude, a spacecraft decreases its velocity relative to the Earth and the GEO arc, which results in a change of location of the spacecraft on the GEO arc. Generally speaking, the greater the increase in altitude, the faster this change of location will occur. For example, a transfer of one degree per day requires an orbital increase of approximately 78 kilometers above GEO. For a transfer of two degrees per day requires an increase of double this amount, or roughly 156 kilometers above GEO.

<sup>174</sup> This difficulty is due to existing limitations in assessing the debris population at these altitudes. Currently, only objects with a diameter of one meter or greater are routinely catalogued at GEO.

<sup>175</sup> *STSC Technical Report on Space Debris* at 28. The report cautions, however, that additional orbital debris measurements in GEO are needed before more accurate risk assessments can be performed. *See id.* Other studies indicate that the annual risk of collision may be significantly greater. *See, e.g.,* Leclair and Sridharan, MIT Lincoln Laboratory, "Probability of Collision in the Geostationary Orbit," in the Proceedings of the Third European Conference on Space Debris (October 2001) (estimating the annual risk of collision for an average operational satellite with other objects greater than one meter in diameter at  $2.0 \times 10^{-4}$ ).

<sup>176</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5609.

provides protection to spacecraft that are operating above GEO either during normal station keeping operations or during transfer maneuvers. For example, Telesat states that it routinely uses orbits that are 100 kilometers above or below GEO for moving satellites from one orbital location to another, and that other operators follow similar practices.<sup>177</sup> The IADC formula also represents an internationally developed consensus for disposal of GEO spacecraft, which has already been adopted into the revised ITU GEO disposal recommendation.

69. We are also adopting the proposal in the *Notice* to provide GEO space station licensees with authority to dispose of space stations at the end of life without the need for a case-by-case authorization from the Commission, provided that the disposal is consistent with the IADC disposal recommendation for GEO spacecraft.<sup>178</sup> No commenters oppose this proposal and its adoption will promote administrative efficiency.

70. Commenters have sought clarification of certain terms of the IADC formula. For example, SIA seeks clarification that the "Area" of the satellite for purposes of calculating the "Area to mass ratio" is calculated on a deployed and on-station basis.<sup>179</sup> Slabinski also agrees that the definition of "Area" in the IADC formula needs clarification and offers suggestions on how to determine this value.<sup>180</sup> We confirm that the area of the satellite should be calculated using a method that reflects its deployed and on-station configuration. The IADC formula is designed to account for the physical characteristics of a spacecraft at the time of disposal. To the extent that antenna and solar panels remain deployed upon disposal, calculations under the IADC formula should account for this fact. The area to be calculated is the average aspect area. We will not specify a detailed methodology for calculating area. However, NASA Safety Standard NSS 1740.14 may prove instructive to licensees in this regard. We note that it would be entirely reasonable for parties to make simplifying assumptions in assessing aspect area, provided that such assumptions bear in mind the objective of ensuring that objects placed into a storage orbit do not re-enter the GEO protected region. Thus, we expect satellite operators to use assumptions which would lead to a disposal orbit in excess of one calculated using higher fidelity methods.

71. We conclude that the use of the IADC formula for evaluating the post-mission disposal plans of GEO space stations is superior to other methods suggested by commenters. Some commenters propose to allow operators the choice of using disposal orbits with an altitude calculated by the IADC formula or 300 kilometers above GEO, whichever is lower.<sup>181</sup> We decline to adopt such a rule, since it would permit space stations that are particularly susceptible to solar radiation pressure to be placed in a disposal altitude of 300 kilometers above GEO, even though this altitude may not be sufficient to prevent such spacecraft from re-entering into the GEO protected region according to the IADC formula. Furthermore, we disagree with commenters that suggest that requiring Commission-licensed space stations to be placed into a disposal orbit constitutes an appropriation of space in violation of the Outer Space Treaty.<sup>182</sup> Just as an initial assignment of an orbital location is not an appropriation of outer space, neither is the use of a storage orbit at end of life, and authorization of a space station to use a storage orbit is consistent with provisions under the Outer Space Treaty that require authorization and continuing

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<sup>177</sup> Telesat Comments at 7.

<sup>178</sup> See Appendix B.

<sup>179</sup> SIA Comments at 14.

<sup>180</sup> Slabinski Reply at 2-3.

<sup>181</sup> SIA Comments at 14; PanAmSat Comments at 5; SES Americom Reply at 6.

<sup>182</sup> UM Space Law Center Comments at 4 (suggesting that formalizing the routine use of a storage orbit in national legislation and regulations could be construed as appropriating space by use or occupation through the means of national legislation in violation of Article II of the Outer Space Treaty).

supervision of the activities of non-governmental entities in outer space.<sup>183</sup> We observe that no U.S. Government agency in charge of implementing the Outer Space Treaty has asserted that use of storage orbits is inconsistent with Article II.

72. We also decline to rely solely on industry practices, as proposed by the majority of commercial satellite operators. We agree with commenters that operators have an economic incentive to maintain a safe environment for their revenue-producing spacecraft,<sup>184</sup> and that this incentive extends to preserving a safe environment for replacement satellites.<sup>185</sup> These economic incentives, however, may be countered by a more immediate incentive to obtain the most revenue from an operational satellite before decommissioning. Maneuvering a spacecraft to a disposal orbit imposes costs on a satellite operator by requiring fuel to be reserved and expended on re-orbiting maneuvers that otherwise could be used to prolong the revenue-producing operations of the spacecraft.<sup>186</sup> Because the last few months of a satellite's operational life can be worth millions of dollars, operators have an economic incentive to extend the operational life of their space stations as long as possible. Furthermore, operators may respond to other short-term pressures, such as the need to bring into use an orbital location specified in an ITU filing, in order to preserve date priority in the ITU process.

73. It is also not clear that the economic effects of failure to dispose of GEO spacecraft at the end of life will be felt by, or limited to, the satellite operator disposing of the spacecraft. Although the economic incentive to maximize revenue-producing activities is immediate, and the consequences of failing to properly dispose of spacecraft at the end of life are not similarly perceived as such, serious ramifications exist for future space station operations that could have repercussions for centuries, if steps are not taken now to address orbital debris. This is true because of the long orbital lifetimes of objects at high altitudes that continue after disposal of the spacecraft. In addition, the consequences of an ineffective disposal may not be felt by the operator performing the disposal. A spacecraft raised to a disposal orbit will have an initial westward drift rate of 1.28° per day for each 100 kilometers in initial elevation above GEO, and thus the eventual effects of an inadequate disposal altitude, as the initial disposal orbit is lowered by physical forces, may be on a location well-removed from the location at which the satellite originated.<sup>187</sup> As a result, operators may react by using disposal orbits that are not adequate for the long-term protection of GEO, but that nonetheless will provide minimal risk to the operator during the timeframe of its planned business activities.

74. The record also indicates that operators follow a wide variety of practices. Some operators voluntarily dispose of their GEO satellites at end of life in accordance with the recommendations of the

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<sup>183</sup> Outer Space Treaty, Article VI.

<sup>184</sup> SIA Comments at 2; PanAmSat Comments at 3; SES Americom Reply at 2; Telesat Reply at 4.

<sup>185</sup> PanAmSat Comments at 3; SIA Comments at 3; SES Americom Reply at 2. Commenters point to the Commission's general policy of granting applications for replacement satellites at the same orbital location so long as the applicant remains qualified to operate its proposed satellite. See, e.g., SIA Comments at 3 (citing *Licensing Space Stations in the Domestic Fixed-Satellite Service*, Report and Order, FCC 85-395, 58 Rad. Reg. 2d. 1267, 1277-79 (1985); *Assignment of Orbital Locations to Space Stations in the Domestic Fixed-Satellite Service*, Report and Order, FCC 88-373, 3 FCC Rcd 6972 n.31 (1988)).

<sup>186</sup> The fuel requirement to re-orbit a GEO satellite 100 kilometers above GEO is estimated at 1.69 kilograms of propellant per 1000 kilograms of mass of the spacecraft. See *1995 Interagency Report* at 36. It has been estimated that the amount of fuel required to maneuver a spacecraft to 300 kilometers above GEO is comparable to three months of lost revenue-producing operations. See *id.*

<sup>187</sup> 1993 ITU Recommendation S.1003 at 3.

ITU and the IADC. Others do not.<sup>188</sup> Further, the record shows that there is substantial variation in the stated practices of operators concerning the minimum altitude above GEO at which disposal is planned, ranging from 100 kilometers above GEO<sup>189</sup> to 192 kilometers above GEO.<sup>190</sup> Although operators claim that such minimum disposal altitudes are sufficient to protect GEO, the target orbits, particularly those in the lower end of this range, could, in fact, result in decommissioned spacecraft drifting back into altitudes at which active GEO communications spacecraft operate.<sup>191</sup>

75. We do not expect that use of the IADC formula as implemented in this decision will be unduly burdensome to space station operators. For GEO spacecraft, the selection of a disposal orbit is primarily an economic, rather than a technical issue. Because the industry practice for GEO spacecraft is generally to use the same propulsion system for end-of-life maneuvers as is used for operational station-keeping, GEO satellites are equipped with the technical means to execute post-mission disposal maneuvers. It is simply a question of how much fuel is budgeted for such maneuvers. To the extent that operators plan to dispose of their spacecraft to an altitude of 300 kilometers above GEO, as recommended by the ITU in 1993, we do not anticipate that the costs of maneuvering a spacecraft to a storage orbit calculated using the IADC formula will be significantly greater for the majority of space stations in the planning stage. In a number of cases, the costs may be less if the space station is not particularly susceptible to solar radiation pressure and the calculated orbit is less than 300 kilometers above GEO.<sup>192</sup> In some instances, there will be additional costs involved with complying with the IADC formula for disposal of GEO spacecraft as compared to the costs that would be incurred under the 1993 ITU recommendation, but we believe that these costs are justified when balanced against potential risk posed in these instances to the continued safe and reliable use of GEO. In these cases, the higher minimum storage altitude is directly related to the increased susceptibility of the spacecraft to solar radiation pressure, which requires that the spacecraft be placed into a higher storage orbit in order to reduce the probability that the spacecraft will re-enter GEO region and interfere with functional space stations. Accordingly, we believe that the additional costs are warranted in these instances in order to achieve the

<sup>188</sup> For example, of the thirteen GEO spacecraft that reached end of life in 2002, only five were disposed of following the IADC formula; the remaining eight spacecraft were re-orbited in a manner that will probably interfere with GEO in the future, or were otherwise disposed of in a manner inconsistent with the IADC formula. See C. Hernández and R. Jehn, *Classification of Geosynchronous Objects*, Issue 5, European Space Agency, European Space Operations Centre, Darmstadt, Germany (2003) at 102-103. Of the five U.S.-licensed satellites that reached end of life in 2002, only two were re-orbited according to the IADC formula. See *id.* In 2001, only two of fourteen GEO spacecraft that reached the end of life were disposed of following the IADC formula. See *id.*, Issue 4 (2002) at 98-99. Only one of four U.S.-licensed GEO spacecraft that reached end of life during 2001 was disposed of following the IADC formula. See *id.* This has led the authors of these reports to conclude that "the reorbiting recommendations which are issued by many national and international organizations since many years are widely ignored" and that a "more rigorous control of the reorbiting practices in GEO is required to protect this unique resource." See *id.*

<sup>189</sup> Telesat Comments at 8.

<sup>190</sup> Inmarsat December 23, 2003, Ex Parte at 1.

<sup>191</sup> As indicated by the IADC guideline, orbital perturbations due to gravitational effects and solar radiation pressure can, depending upon a spacecraft's physical characteristics, result in changes of satellite orbits by as much as 235 kilometers, although such changes for communications satellites typically range from 60 to 90 kilometers. Communications spacecraft typically operate, with normal station-keeping parameters, at altitudes up to 25 kilometers above GEO. Thus, a spacecraft disposed to 100 kilometers above GEO could re-enter the region in which operational GEO spacecraft reside.

<sup>192</sup> For example, an analysis of a typical Boeing 601 spacecraft, with solar panel fully deployed, results in an area-to-mass ratio of approximately 0.0166m<sup>2</sup>/kg (average aspect area, 41m<sup>2</sup>, and dry mass, 2477kg). Using the IADC formula with an assumed spacecraft solar radiation pressure coefficient of 1.5 kg/m (value ranges from 1 to 2), the post-mission disposal altitude for this spacecraft is approximately 260 km above GEO.

public interest in minimizing the hazard posed by orbital debris to the continued safe and reliable use of GEO.

76. Accordingly, we will require entities seeking an FCC license to operate a GEO space station, or requesting authorization from the Commission to operate with a non-U.S.-licensed space stations to serve the U.S. market under our foreign entry provisions, to demonstrate as part of its orbital debris mitigation disclosure that the operator will be capable of maneuvering its spacecraft at end of life to a disposal altitude with a perigee calculated by use of the IADC formula. As part of this demonstration, entities should provide the calculations that were used in deriving the disposal altitude. As discussed above, simplifying assumptions may be made when applying the IADC formula, provided that such assumptions lead to a disposal orbit in excess of one calculated using higher fidelity methods. Entities who plan to operate or communicate with a GEO spacecraft that will be disposed of at end of life in a manner inconsistent with IADC formula must seek a waiver of our rules as part of their application for Commission authorization.

(i) Grandfathering

77. Many commercial operators of GEO satellites urge the Commission to apply GEO disposal rules only prospectively and to exempt, or “grandfather,” all satellites that are currently on-orbit or under physical construction.<sup>193</sup> In support of this position, these operators assert that application of the IADC formula to satellites already in orbit would constitute an impermissibly retroactive application of a new rule. In addition, they claim that application of the IADC formula to spacecraft currently on-orbit would impose large additional costs on operators that are not balanced by a corresponding benefit to the public.

78. As an initial point, we stress that application of the IADC formula to existing spacecraft would not be impermissible under either the Administrative Procedure Act or Commission precedent, as purported by some space station operators. Operators cite to *Bowen*<sup>194</sup> and its progeny in support of this argument.<sup>195</sup> Courts have clarified, however, that *Bowen* is limited to situations in which an agency “alter[s] the past legal consequences of past actions” (emphasis in original).<sup>196</sup> Accordingly, application of an agency’s rule is impermissibly retroactive when it “would impair rights a party possessed when he acted, increase a party’s liability for past conduct, or impose new duties with respect to transactions already completed.”<sup>197</sup> This type of “primary” retroactivity is not at issue here. Application of the IADC formula would extend only to disposals that will occur in the future and would not alter the consequences or liability for disposals already completed. Furthermore, application of the IADC formula would not alter any right operators currently possess. Authorization from the Commission has always been required for radiocommunications involving FCC-licensed space stations, including those used to command

<sup>193</sup> See SIA Comments at 15 (disposal rules should not apply to satellites in orbit at the time the rule is adopted); PanAmSat Comments at 6 (disposal rules should not apply to any satellite that is already in orbit); SES Americom Reply Comments at 6 (new regulations should only apply prospectively); EchoStar January 30, 2004 Ex Parte at 2 (Commission should grandfather satellites in orbit as of the effective date of disposal rule); Inmarsat February 4, 2004 Ex Parte at 2 (rules should not apply to spacecraft that are in-orbit or currently under physical construction).

<sup>194</sup> *Bowen v. Georgetown University Hospital*, 488 U.S. 204 (1988).

<sup>195</sup> See PanAmSat Comments at 6 (citing *Bowen* and *National Mining Assoc. v. United States Dept. of Interior*, 177 F.3d 1 (D.C. Cir. 1999)); EchoStar January 30, 2004 Ex Parte at 2.

<sup>196</sup> See *Celotronic Telemetry, Inc. v. FCC*, 272 F.3d 585, 588 (D.C. Cir. 2001) (*Celotronic*) (citing *Bowen*, 488 U.S. at 219 (Scalia, J., concurring)).

<sup>197</sup> *Celotronic*, 272 F.3d at 588 (citing *Landgraf v. USI Film Products*, 511 U.S. 244, 280 (1994)).

disposal maneuvers.<sup>198</sup> Our rules to date have not vested any right for operators to dispose of their spacecraft in a particular manner. We are also unaware of any authorization for a GEO space station currently on orbit that provides a licensee with authority for post-mission disposal and the maneuvers and radio transmissions necessary to effectuate it. Instead, we have always reviewed applications for post-mission disposal of FCC-licensed space stations on a case-by-case basis.<sup>199</sup> Thus, evaluating the post-mission disposal plans of spacecraft already on orbit consistent with the IADC formula would not alter any existing right of operators to dispose of their spacecraft in a particular manner.<sup>200</sup>

79. Nonetheless, we agree that, in light of the potentially significant financial impact of this new requirement, a transition period sufficient to permit operators to adjust their projections and operations is in the public interest. Based on comments and *ex parte* presentations, it appears that a number of operators currently plan for disposal of their GEO spacecraft at minimum perigee altitudes of 100-150 kilometers above GEO, which is significantly lower than the minimum perigee altitudes calculated by use of the IADC formula.<sup>201</sup> Operators state that the additional fuel required to dispose of currently operational spacecraft at altitudes higher than those for which disposal of these satellites are planned would shorten the spacecraft's expected operational lifetimes by an average of one to three months compared to the use of a lower disposal altitude of, for example, 150 kilometers.<sup>202</sup> Three months represents a reduction of somewhat less than two percent of the mission life of a satellite with a 15-year operational lifetime. Operators also indicate that as a result of lost operational lifetime, the overall cost of using the IADC formula to dispose of on orbit spacecraft could amount to hundreds of millions of dollars

<sup>198</sup> 47 U.S.C. § 301. Furthermore, an FCC-licensed GEO space station license requires a licensee to operate within certain station keeping parameters. Operations outside of these parameters, such as during maneuvers to a storage orbit at end of life, are not typically included in an operator's space station license and require specific additional authorization from the Commission to effectuate.

<sup>199</sup> See Section II.B, *infra*. In a number of cases, staff has, particularly in recent years as information has become available concerning variations in disposal practices of GEO spacecraft, included conditions in authorizations requiring disposal of GEO spacecraft consistent with the ITU recommendation, or requiring that licensees maintain the capability to dispose of their spacecraft consistent with the ITU recommendation. See, e.g., *PanAmSat Licensee Corp.*, File No. SAT-STA-20030805-00141 (filed August 18, 2003); *Galaxy IIR STA Grant* (conditioning grant of special temporary authority on licensee maintaining the capability to dispose of spacecraft at an altitude with a perigee of no less than 300 kilometers above GEO).

<sup>200</sup> Even if adoption of a post-mission disposal requirement alters the expectations of space station operators, the Commission has held that licensees have no vested right to an unchanged regulatory scheme throughout their license term. See Amendment of Part 1 of the Commission's Rules – Competitive Bidding Procedures, *Order on Reconsideration*, FCC 00-274, 15 FCC Rcd 15293, 15396 (2000), *pet. for recon. denied*, 18 FCC Rcd 10180 (2003). Furthermore, it is undisputed that the Commission has the power to alter existing licenses by a rulemaking procedure such as this. See *Celotronic*, 272 F.3d at 589 (citing *United States v. Storer Broadcasting Co.*, 351 U.S. 192, 205 (1956); *National Broadcasting Co. v. United States*, 319 U.S. 190, 225 (1943); *Committee for Effective Cellular Rules v. FCC*, 53 F.3d 1309, 1319-20 (D.C. Cir. 1995); *WBEN, Inc. v. FCC*, 396 F.2d 601, 617-18 (2d Cir. 1968)).

<sup>201</sup> See Telesat Comments at 8; EchoStar January 30, 2004, Ex Parte at 1; SES Americom January 14, 2004, Ex Parte at 3; PanAmSat January 8, 2004, Ex Parte at 2.

<sup>202</sup> See SES Americom January 15 Ex Parte at 3. Other filings in the record support this conclusion. Telesat states that about one month of operational lifetime is lost in order to maneuver to a storage altitude 100-150 kilometers above GEO and that "two to three times" as much fuel is necessary to maneuver to 300 kilometers above GEO. See Telesat Comments at 8. EchoStar states that approximately four months of service life is lost by maneuvering to 300 kilometers above GEO. See EchoStar January 30 Ex Parte at 2.

in lost revenue to the industry.<sup>203</sup> While it is impossible to state the precise loss of operator revenue that would result from requiring on-orbit spacecraft to maneuver existing on-orbit spacecraft at end of life to disposal orbits calculated by use of the IADC formula, we accept that this loss of revenue could be significant and must be balanced against the public benefits of application of the IADC formula to all spacecraft, including those already on orbit.

80. We conclude that the risks resulting from grandfathering, such as increased risks of collision or risks associated with other fragmentation events occurring in the GEO region, currently are not sufficient to outweigh the potential financial hardships involved in applying the IADC formula to all GEO spacecraft currently on orbit. The record does not demonstrate the amount of increased risk that would result from a finite number of existing on-orbit spacecraft being disposed of at altitudes below those calculated by use of the IADC formula, but at an altitude from which the disposed spacecraft would not pose a risk to normally station-kept satellites.<sup>204</sup> Given the existing low spatial density of the GEO regions, there is insufficient evidence on the record at this time to conclude that this increase in risk would be significant.

81. Accordingly, we will grandfather all on orbit GEO spacecraft that were launched as of the release of the *Notice* in this proceeding.<sup>205</sup> We will not, however, grandfather all GEO spacecraft currently on-orbit or under construction as of the release of this Second Report and Order, as urged by some commenters. Operators generally agree that notice of our intent to implement the IADC formula was provided by the release of the *Orbital Debris Notice*.<sup>206</sup> Thus, equity concerns that support the exemption of satellites launched prior to the release of the *Notice* are not present with those satellites launched after the release when operators were on notice of the possible use of the IADC formula to evaluate the post-mission disposal of GEO spacecraft.<sup>207</sup> Operators that launched satellites after the release of the *Notice* were on notice of our intent to use the IADC formula. Furthermore, the long expected lifetimes of satellites launched since the release of the *Orbital Debris Notice* should allow operators reasonable time to take the IADC formula into account when planning for the disposal of their spacecraft.

82. Finally, we will not specify a minimum altitude for disposal of grandfathered satellites. The stated current practice of several U.S. operators is, barring catastrophic hardware failures, to execute end-of-life maneuvers that result in a disposal altitude no less than 150 kilometers above GEO.<sup>208</sup> Some non-

<sup>203</sup> SIA February 4 Ex Parte at 1. See also SES Americom January 14 Ex Parte at 6 (claiming \$77 million in lost revenue from application of the IADC disposal formula to its existing on-orbit GEO fleet); PanAmSat January Ex Parte at 2 (claiming \$140 million in lost revenue).

<sup>204</sup> We estimate that there are approximately 80 or fewer FCC-licensed GEO spacecraft that would be eligible for grandfathering.

<sup>205</sup> The *Orbital Debris Notice* was released on March 18, 2002.

<sup>206</sup> See SES Americom January 14 Ex Parte at 3 (stating that release of the *Notice* "marks the first time the Commission indicated that it would replace industry self-regulation with new rules"). See also SIA February 4, 2004 Ex Parte at 2 (stating that, "At a minimum, spacecraft launched prior to the release of the [*Notice*] should be grandfathered.").

<sup>207</sup> EchoStar argues that release of the *Notice* did not provide sufficient notice to justify "retroactive" application of disposal rules. See EchoStar January 30 Ex Parte at 2. EchoStar's argument, however, is based on the premise that application of rules to future disposal is contrary to the APA and Supreme Court's decision in *Bowen*. Since that is not the case, as discussed above, EchoStar's argument is not persuasive.

<sup>208</sup> A number of operators have exceeded this minimum, see, e.g., Letter from Karis A. Hastings, Counsel for SES Americom, to Marlene H. Dortch, Secretary, FCC, dated February 12, 2004 (reporting the deorbit of the GSTAR4 satellite to an altitude more than 300 kilometers above GEO), and at least one U.S. licensed operator (Intelsat) has, (continued....)

U.S. operators have indicated a disposal perigee altitude range of 100-192 kilometers above GEO.<sup>209</sup> We urge operators to continue to evaluate the safety of any such practice in light of developing knowledge about risks in GEO and the surrounding region, and in light of the conditions of any particular spacecraft.<sup>210</sup> We also urge operators to exercise the highest standards, and applaud those who have voluntarily adopted practices, involving substantial margins of safety, designed to protect the unique and important geostationary-Earth orbit resource.<sup>211</sup>

**b. NGSO Space Stations**

83. *Background.* The *Orbital Debris Notice* sought comment on whether to adopt the U.S. Government Standard Practices as rules applicable to the post-mission disposal of new low-Earth orbit systems and to replacement satellites for such existing systems.<sup>212</sup> In particular, it noted that the U.S. Government Standard Practices calls for the disposal of LEO satellites at end of life either through immediate atmospheric re-entry or through the placement of a spacecraft into an orbit from which it will re-enter the Earth's atmosphere within 25 years. The *Notice* observed that the U.S. Government Standard Practices, if strictly applied, could have a significant impact on the deployment of spacecraft in certain orbital regimes or using certain types of technologies. Specifically, the *Notice* noted that spacecraft operating with circular orbits in the region of approximately 1000 to 1600 kilometers would be required to budget a substantial amount of fuel in order to either lower the spacecraft's perigee orbit to an altitude from within which it would re-enter the Earth's atmosphere within 25 years, or to boost the spacecraft into a storage orbit between low-Earth orbit and medium earth orbit.<sup>213</sup> In addition, it noted that many small satellite systems are currently deployed with only minimal on-board maneuvering capabilities. Thus, the *Notice* indicated that adoption of the U.S. Government Standard Practices into the Commission's rules could effectively preclude operations of such spacecraft at higher orbital altitudes. Finally, the *Notice* sought comment concerning the end-of-life disposal of spacecraft involving atmospheric re-entry.<sup>214</sup>

84. *Discussion.* As a result of the disclosure requirements we are adopting, we will receive information concerning end-of-life disposal for NGSO satellites. We intend to examine such disclosures on a case-by-case basis in light of the U.S. Government Standard Practices and the IADC Guidelines. In particular, we intend to examine such disclosures to determine, for spacecraft with orbits either wholly within, or passing through, the LEO region, whether the spacecraft will be disposed of at end of life either

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barring catastrophic failure, retired spacecraft consistent with the IADC recommendation in recent years. See C. Hernández and R. Jehn, *Classification of Geosynchronous Objects*, Issue 6, European Space Agency, European Space Operations Centre, Darmstadt, Germany (2004) at 109.

<sup>209</sup> Telesat Comments at 8; Inmarsat Dec. 23, 2003, Ex Parte at 1.

<sup>210</sup> For example, it may be preferable to dispose of a spacecraft in the GEO region, if that spacecraft faces a known and high risk of explosion in connection with thruster firings, because the consequences of an explosive fragmentation of the spacecraft considerably outweigh the future collision risk associated with disposal in GEO of an intact spacecraft.

<sup>211</sup> Note that our grandfathering action is not intended to address any issues of liability that may arise as a result of grandfathered spacecraft. See *The T.J. Hooper et.al. v. Northern Barge Corporation, et.al.*, 60 F.2d 737 (2<sup>nd</sup> Cir., 1932) (adoption by some ships of a practice of carrying radio sets to receive weather reports, even though not required by statute, considered relevant in assessing liability).

<sup>212</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5609.

<sup>213</sup> *Id.*

<sup>214</sup> *Id.*

through immediate atmospheric re-entry, through the placement of a spacecraft into an orbit from which it will re-enter the Earth's atmosphere within 25 years, or through boosting the spacecraft into an orbit with a perigee above the LEO region.<sup>215</sup> As a general matter, these methods of post-mission disposal suggest that the space station will operate consistent with the public interest. We have already been evaluating the post-mission disposal plans of Commission-licensed LEO space stations based on this practice on a case-by-case basis.<sup>216</sup> If a disclosure indicates that a space station will not use one of these methods, the Commission may be required to seek further information, or ultimately to condition or withhold approval for the space station.

85. We recognize that changes in the design and operation of certain types of LEO spacecraft may be necessary in order to follow these practices and may limit an operator's ability to deploy spacecraft in certain orbital regimes or use certain spacecraft designs. On balance, however, we believe closer adherence to these practices is warranted in order to limit the growth of orbital debris in LEO. Without such disposal practices, objects could remain in low-Earth orbit for decades or centuries after the end of their useful lives and could become the source of collisions that produce additional debris spread over a wide area. By requiring LEO space stations to be removed from orbit within 25 years of the completion of their mission, the probability that such spacecraft will contribute to the creation of additional orbital debris is greatly diminished. The IADC Guidelines specifically note that an IADC study examined the effect of post-mission orbital lifetime limitations on collision rates and debris population growth and found 25 years to be a reasonable and appropriate lifetime limit.<sup>217</sup> None of the commenters raising concerns about adherence to LEO end-of-life practices takes issue with the general desirability of limiting debris growth. While closer adherence to these practices may require changes in spacecraft design, choice of a different orbit, or other changes, it appears that such changes would serve the public interest, and would help to ensure long-term, affordable access to space, as well as the continued availability, reliability, and continuity of space-based services for U.S. consumers.

86. We decline to adopt as rules the stricter disposal requirements for certain classes of LEO space stations, as recommended by some commenters in this proceeding. For example, Ecliptic proposes that large microsat constellations, consisting of 100 or more spacecraft, be limited to orbital altitudes from which they will re-enter the Earth's atmosphere within five years of mission completion, due to their lack of propulsion systems and low rate of reliability of individual spacecraft.<sup>218</sup> Ecliptic also recommends that all microsats, regardless of constellation size, be limited to altitudes of no higher than 625 kilometers at perigee.<sup>219</sup> L'Garde also suggests placing limits on the altitudes at which microsats can operate.<sup>220</sup> Both Ecliptic and L'Garde suggest that microsats, and other NGSO satellites lacking propulsion, be required to incorporate methods, such as the use of inflatable devices, to decrease their orbital lifetimes by

<sup>215</sup> The IADC Guidelines, unlike the U.S. Government Standard Practices, do not explicitly provide for the "boost" method of end-of-life disposal. However, because this method would remove the spacecraft from the LEO region, it would meet the primary goal of protecting this highly utilized region. Any such disposal plan should address, and will be analyzed, consistent our discussion, *infra*, concerning MEO disposal, to determine whether the disposal orbits chosen would be sufficiently stable to remain out of LEO and GEO, and to avoid physical interference with highly utilized MEO orbits.

<sup>216</sup> See, e.g., *Orbital Communications Corp.*, Order and Authorization, DA 02-772, 17 FCC Rcd 6337 (2002) (conditioning approval of an increase in the proposed orbital altitude of a licensee's Little LEO satellite constellation on measures being taken to reduce the orbital lifetime of the satellites).

<sup>217</sup> IADC Guidelines at Section 5.3.2.

<sup>218</sup> Ecliptic Comments at 7.

<sup>219</sup> *Id.*

<sup>220</sup> L'Garde Comments at 5.

means of atmospheric drag.<sup>221</sup> Although we agree that each of the measures proposed would appear to be a reasonable means by which a space station operator could mitigate debris under the circumstances presented by the commenters, we do not believe that adopting detailed rules of this type is appropriate at this time. We anticipate that as experience with debris mitigation measures grows, it may be possible to provide more detailed guidelines of this type. For now, however, we believe it is appropriate to address cases involving NGSO disposal as they arise. In light of concerns raised about the low rate of reliability of individual spacecraft, however, we note that it may be appropriate in some instances to address this issue as part of a debris mitigation showing, particularly with respect to satellite designs having known and significant failure rates, or where a satellite has been designed with an acceptable failure rate well below commercial industry norms. Reliability may be relevant to both assessment of whether the satellite will meet end-of-life goals, and to assessment of whether the public interest benefits arising from the satellite's activities will, in fact, be provided.

87. We will also continue to evaluate post-mission disposal plans for space stations in orbits that do not pass through LEO or GEO, such as highly elliptical or medium Earth orbits, on a case-by-case basis. The IADC Guidelines call for the end-of-life maneuvering of space stations that are using orbits other than LEO or GEO in order to reduce their orbital lifetimes to the 25 year timeframe for post-mission disposal of LEO spacecraft, or for relocation of such space stations into storage orbits if they cause interference with highly utilized orbit regions.<sup>222</sup> The IADC Guidelines do not, however, provide detailed recommendations for accomplishing these objectives. We note that technical studies are on-going to evaluate the long-term stability of disposal orbits in MEO.<sup>223</sup> Entities relying on such orbits should indicate with specificity what orbit will be used for disposal, and whether that orbit has been analyzed to determine its long-term stability.

88. Finally, the *Orbital Debris Notice* proposed to continue to require applicants proposing to dispose of spacecraft by means of atmospheric re-entry to provide an assessment of the risk of human casualty from such atmospheric re-entry. The *Notice* observed that the U.S. Government Standard Practices provide that any such disposal of a spacecraft should present a risk of human casualty of no more than 1 in 10,000.<sup>224</sup> The *Notice* observed that this assessment has been required in previous Commission case-by-case licensing decisions and is based on standards established by NASA Safety Standard NSS 1740.14 for debris re-entry and incorporated in the U.S. Government Standard Practices.<sup>225</sup> We will continue to require entities proposing to dispose of spacecraft by means of atmospheric re-entry to assess the risk of human casualty from such atmospheric re-entry and will review these assessments on a case-by-case basis.<sup>226</sup> No party to this proceeding opposed the continued evaluation of the human casualty risk assessment according to the standards of the NASA and U.S. Government Standard Practices. Entities may wish to look to the U.S. Government Standard Practices and NASA Safety Standard NSS 1740.14 (and any revisions to that standard) as a guide when preparing their assessment

<sup>221</sup> Ecliptic Comments at 7; L'Garde at 6.

<sup>222</sup> IADC Guidelines at Section 5.3.3.

<sup>223</sup> See, e.g., C.C. Chao and R.A. Gick, "Long-Term Evolution of Navigation Satellite Orbits: PS/GLONASS/GALILEO" (COSPAR02-A-02858)(PEDAS1-B1.4-0051-02).

<sup>224</sup> *Orbital Debris Notice*, 17 FCC Rcd at 5610.

<sup>225</sup> *Id.*

<sup>226</sup> In general, an assessment should include an estimate as to whether portions of the spacecraft will survive re-entry and reach the surface of the Earth, as well as an estimate of the resulting probability of human casualty.

and certification.<sup>227</sup>

c. Fuel Matters

89. *Background.* The *Orbital Debris Notice* sought comment whether an FCC rule is necessary to ensure that spacecraft reserve adequate fuel supplies at the end of useful life to execute post-mission disposal maneuvers, such as de-orbiting or removal to storage orbits.<sup>228</sup> The *Notice* noted that the reservation and expenditure of fuel for post-mission disposal maneuvers comes at the expense of income-producing activities, and sought comment whether measures might be necessary to ensure that spacecraft maintain adequate fuel at end of life, such as requiring operators to report the availability of fuel adequate to execute planned disposal maneuvers.<sup>229</sup> In this regard, it observed that one group of experts has recommended the adoption of reporting requirements for satellites reaching end of life, concerning fuel reserves and end-of-life plans.<sup>230</sup> The *Notice* also sought comment on any other matters, including any technological developments, which might affect end-of-life procedures.

90. *Discussion.* We agree with commenters that it is unnecessary at this time for the Commission to mandate specific fuel levels for post-mission disposal maneuvers.<sup>231</sup> In the case of GEO spacecraft, we have specified that the IADC formula should be used to calculate the minimum perigee for an appropriate storage orbit for satellites launched subsequent to the release of the *Notice*. Satellite operators are in the best position to apply the IADC formula and determine the corresponding amount of fuel that must be reserved for a particular spacecraft in order to achieve the corresponding minimum perigee altitude. Likewise, operators of NGSO systems are also in the best position to determine how they will dispose of their spacecraft at the end of life and the corresponding amount of fuel to reserve to achieve disposal, if in fact the spacecraft plans to use propulsion as a means of disposal. We believe that operators have adequate incentive to reserve adequate fuel supplies to comply with our post-mission disposal requirement without the need for additional Commission mandates regarding fuel supplies.<sup>232</sup>

91. We conclude, however, that the public interest would be served by having space station operators disclose, as part of applications for Commission authorizations, the quantity of fuel – if any – they intend to reserve for post-mission disposal of their spacecraft, as well as the methodology used to derive that quantity, including the methods used to determine and address fuel gauging uncertainty. We conclude that such a requirement serves the public interest by demonstrating, prior to receiving Commission authority, that the space station operator has adequately planned for the post-mission disposal of its spacecraft. While this disclosure requirement does not eliminate the possibility of inadequate disposal as the result of operator error or unforeseen emergencies, as noted by one commenter,<sup>233</sup> it does provide reasonable assurance that an operator has addressed post-mission disposal

<sup>227</sup> These documents and software tools that may prove useful in completing debris mitigation statements, including any casualty risk assessment, can be found at the NASA orbital debris website, [www.orbitaldebris.jsc.nasa.gov](http://www.orbitaldebris.jsc.nasa.gov).

<sup>228</sup> *Id.* at 5609.

<sup>229</sup> *Id.* at 5602-03.

<sup>230</sup> *Id.* at 5609 (citing *AIAA 2001 Report* at 12).

<sup>231</sup> SIA Comments at 9-10, 16.

<sup>232</sup> In this respect, we agree with comments that argue that fuel gauging requirements are unnecessary if there are adequate penalties for non-compliance with disposal requirements. See MIT Lincoln Laboratories Comments at 3. We acknowledge that fuel gauging is “not an exact science,” see SIA Comments at 10, and do not anticipate taking action against improper disposal of Commission-licensed space stations that result from fuel levels calculations that prove to be erroneous, but that are nonetheless made in good faith.

<sup>233</sup> Slabinski Comments at 1.